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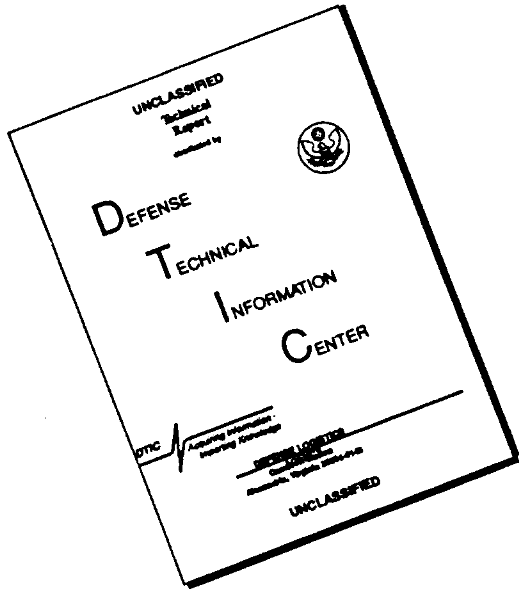

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AR-TSD-CR

COMPILATION OF BLAST PARAMETERS OF SELECTED HIGH EXPLOSIVES, PROPELLANTS, AND PYROTECHNICS IN SURFACE BURST CONFIGURATIONS

by
F.L. McIntyre

PROJECT COORDINATOR
Robert A. Brack

Bob Kukuvka
Joe Caltagirone

January 1987

NASA NATIONAL SPACE TECHNOLOGY LABORATORIES
SVERDRUP TECHNOLOGY INCORPORATED
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US ARMY
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Armament Engineering Directorate
Dover, New Jersey 07801

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report is a compilation of TNT equivalency test programs of selected high explosives, propellants, and pyrotechnics. These tests were originally conducted in various test agencies and reported in individual reports of varying formats. In all, there were 41 materials tested under various MMT projects. This report compiles all test data from the various programs and presents it in a standardized format.

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18. SUBJECT TERMS (Cont'd)

RDX
Composition C4
Composition A5
Composition A3
M/O propellant
WC 844 ball powder
Nitrocellulose
M26 El propellant
Tetracene
M718/741 155mm projectile
M1 propelling charge
Lead styphnate
Lead oxide
Black powder
M1 propellant
Composition B
Guanidine nitrate
Nitroquanidine
Benite propellant
B2 NACA propellant
JA-2 propellant
N5 propellant
R284 trace mixture
I559 igniter mixture
I560 subigniter mixture
105mm illuminant mixture
M49A1 trip flare illuminant mixture
Aluminum/potassium perchlorate
Titanium potassium perchlorate

PREFACE

This work was performed at the NASA National Space Technology Laboratories (NSTL) under the direction of the AMCCOM Resident Operations Office (AROO) by Computer Sciences Corporation as NASA's technical contractor. Experimental work was conducted beginning in 1970 and completed in 1986.

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ACKNOWLEDGEMENTS

The author wishes to acknowledge the technical assistance of Mr. Robert Kukuvka and J. Caltagirone of ARDEC, Dover, New Jersey who were the project coordinators and provided valuable assistance in the completion of this document. Larry Mars, Sverdrup Technology, Inc. who as the project engineer performed many of these tests, and to the other personnel involved in the actual conduct of the tests that made this data available.

SUMMARY

The airblast overpressure and positive impulse parameters of 20 bulk high explosives (HE), one HE submunition, two HE end-item munitions, 13, bulk propellant compositions, two propelling charges in an end-item configuration, and eight pyrotechnic mixtures were compared with the known characteristics of hemispherical TNT data[1] to derive the TNT equivalency values. These materials were tested in a manufacturing in-plant processing geometries and in various standard shipping containers.This report is the compilation of the blast pressures, scaled positive impulse, and TNT equivalency values for these materials. The tables below list the various materials and end-items, geometries, and the charge weights that were tested.

Bulk Explosives

Sample Material	Test Geometry	Charge Weight (kg)
Composition A3	Orthorhombic	13.6, 27.2, and 54.4
Composition A5	Orthorhombic Cylindrical	11.3, 27.2, and 68.0
Composition B	Hemispheres, Spheres Cylindrical	0.45, 0.49, 0.68, 1.22 1.35, and 1.37
Composition C4	Orthorhombic	17.0, and 27.2
Cyclotol 70/30	Orthorhombic Truncated Prism	13.6, 27.2, 45.4, and 68.0
EAK	Cylindrical	11.34, and 22.7
Guanidine Nitrate	Orthorhombic	68.5, 108.9, 217.7, and 362.9
HMX	Orthorhombic Cylindrical	22.7, 27.2, 45.4, and 54.4
LX-14	Orthorhombic Cylindrical	0.45, 1.36, 27.2, 54.4, 68.0, and 72.6
Nitrocellulose	Orthorhombic Cylindrical	11.3, 22.7, 41.9, and 45.0
Nitroglycerine	Cylindrical	0.45, 0.91, and 1.81
Nitroguanidine	Orthorhombic	2.7, 10.9, 22.7, and 49.9
Octol 75/25	Orthorhombic Truncated Prism	13.6, 27.2, 45.5, and 68.0
PBXC-203	Cylindrical	1.4, 2.8, 2.9, 5.2, 5.6, and 10.4
PBXN-106 (Precoat)	Otrhorhombic	27.22, 45.36, and 90.72
PBXN-109 (Precoat)	Orthorhombic	27.22, 45.36, and 90.72
RDX	Orthorhombic Cylindrical	22.7, 27.2, 45.4, and 54.4
RDX Slurry	Cylindrical	0.91, and 1
Lead Azide	Orthorhombic Cylindrical	0.67, 0.91, and 22.7
Lead Styphnate	Orthorhombic Cylindrical	0.71, 0.91, 22.7, and 68.0
Tetracene	Orthorhombic Cylindrical	0.29, and 4.5

Bulk Explosives (continued)

Sample Material	Test Geometry	Charge Weight (kg)
TNT	Orthorhombic Cylindrical Truncated Prism	27.2, 45.5, 68.0, and 90.7

Sub munitions and End-items

Sample Material	Test Geometry	Charge Weight (kg)
M42 Grenades	Tray of 64	1.9
M483, 155mm Projectile	Single Round	2.7
M718/741, 155mm	Single Round	5.1
Projectile	Two Rounds	10.2
	Pallet of Eight	41.0

Propellants and Propelling Charge

Sample Material	Test Geometry	Charge Weight (kg)
Black Powder	Orthorhombic Hemispherical	226.7, 454.0 907.2, 1451.5, and 2041.1
Benite Propellant	Orthorhombic	10.4, and 41.8
BS-NACO Propellant	Cylindrical Truncated Prism	22.7, and 49.9
DIGL-RP Propellant		
(I5420)	Orthorhombic	25.0, 49.9, and 74.8
(I5421)	Cylindrical	10.0, 20.0, and 30.0
(I5422)	Orthorhombic	9.1
JA-2 Propellant (L5460)	Orthorhombic Cylindrical	16.3, 24.9, 32.7, 33.1 and 49.9
M1 Propellant		
Single Perforation	Cylindrical Truncated Prism	11.3, 12.2, 19.5, and 22.7
Multiple Perforation	Cylindrical	15.9, and 24.9
M6 Propellant	Cylindrical	26.1
	Truncated Prism	22.7
M10 Propellant	Orthorhombic	2.7, 11.3, 45.5, and 68.5
M26E1 Propellant	Orthorhombic	3.6, 17.7, 27.2, 29.5, 71.7 430.9, 721.2, and 884.5
M30A1 Propellant		
Single Perforation	Orthorhombic Cylindrical	13.6,20.2, 21.8, 22.7, and 24.9
Multiple Perforation	Orthorhombic Cylindrical	17.2, 23.1, 24.0, 24.9, and 26.3
M31A1E1 Propellant	Cylindrical	27.2, and 54.4

Propellants and Propelling Charge (continued)

Sample Material	Test Geometry	Charge Weight (kg)
N5 Propellant	Cylindrical	15.9, and 31.8
WC844 Propellant	Orthorhombic Cylindrical	22.7, 36.3, 45.4, and 72.6
XM37 Propellant, RAP, M549	Cylindrical	1.02, 1.91, 12.19, 16.26, and 22.97

Pyrotechnic Mixtures

Sample Material	Test Geometry	Charge Weight (kg)
R284 Tracer Mixture	Cylindrical	1.1 and 5.4
I559 Igniter Mixture	Cylindrical	1.1 and 5.4
I560 Igniter Mixture	Cylindrical	1.1 and 5.4
105mm Illuminant Mix	Cylindrical	22.7
M49 Trip Flare Illuminant Mixture	Cylindrical	22.7
105mm First Fire Mixture	Cylindrical	2.3 and 4.5
Ignition Mixture	Cylindrical	0.05, 0.15 and 0.36
Ignition Mixture	Cylindrical	0.10

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INTRODUCTION

BACKGROUND

In the early 1970's, United States Army-Wide Expansion Programs were begun to upgrade the existing, and developing new explosives manufacturing load assembly, and packout (LAP) facilities. Specifically, this program was the US Army Munition's Production Base Modernization and Expansion Program. As a part of this overall program, The Energetics System Process Division, Large Caliber Weapons System Laboratory (ARDC), Dover, New Jersey, is engaged in the development of safety criteria. The primary goal of this program was to provide for substantial increases in productivity, cost-effectiveness, and improvement in facility design to enhance safety and awareness of the magnitude for potential hazards.

Past methods used for fitting and design of individual components of explosive manufacturing and related facilities were predicated solely upon gross quantities of the hazardous material present for a given operation. While being cost-effective and providing for an acceptable safety margin, it is possible to design and operate facilities based upon the requirements of a particular hazardous material involved in the operation. Specifically, it is impractical to design for a Class-/Division 1.1 explosive material with an explosive yield equal that of TNT, if the actual material is a propellant with only a 75% yield equal to TNT. Conversely, danger exists in under designing facilities when the explosive yield due to the geometry or configuration is twice that of TNT. Designing the facility and knowing the effective yield and hazards potential, then allowing for an acceptable safety margin, would be cost effective.

The primary objective of the individual test programs was to determine the maximum airblast output from the detonation of bulk and/or cast explosives, end-item munitions, propellants, and pyrotechnics in terms of peak pressure and impulse for geometries found in manufacturing, transporting and/or storage. The measured values were representative of the realistic hazard potential yield of a given material as the pressure and impulse values include both incident and reflected side-on values as found in actual manufacturing situations. Thus, when these measured values are compared with known characteristics of hemispherical surface burst TNT[1] with a length to diameter (L/D) ratio of 1:1, the reported values will generally be greater than expected for classical hemispherical values. Specifically, each material was tested in in-plant configurations representing hoppers, storage bins, transfer boxes, feeder tubs, dryer beds, transfer carts, powder barrels, bags, beakers, and press die configurations. These configurations were representative of orthorhombic, cylindrical, hemispherical, spherical, and truncated prisms with length to diameter ratios ranging from 0.1:1 to 20:1. The physical characteristics of the explosive materials were dry powders, cast charges, explosives wetted with alcohol, pressed billets, chips, flakes, slurries, and extruded rods. The physical characteristics of the propellants were single multi-perforated webs, varied web sizes, stick propellants and slurries in various drying states. The pyrotechnic mixtures were tested in dried powder forms.

The experiments were conducted by four different experimenters using several different state-of-the-art instrumentation systems. However, each experimenter followed the same standardized test procedure as determined by the Energetic Systems Process Division, Large Caliber Weapon System Laboratory, ARDC, Dover, New Jersey. Since the tests were conducted under standardized conditions and compared to the same reference material, the data by each experimenter could be treated in the same manner and compiled using a standard format specifically for this report.

OBJECTIVE

The objective of this report was to compile all of the readily available TNT equivalency data as tested by the differernt government and industrial agencies. All data, though empirically derived by different experimenters, was evaluated and analyzed in a consistant format that is easily accessible and provides for a comprehensive and ready reference for engineers, safety representatives, project leaders, and manufacturing personnel. The uniqueness of the data presented in this compendium, is that it was obtained using the latest state-of-the-art instrumentation systems and represents the potential yield of a given material under realistic manufacturing conditions.

EXPERIMENTAL METHODS

BACKGROUND

TNT equivalency testing of explosives, explosive end-items, propellants, and pyrotechnics was conducted to determine peak positive overpressure and positive impulse resulting from the detonation of the test material and comparing these values to the same parameters produced by hemispherical surface bursts of TNT. Peak pressure and positive impulse were compared with one another to determine TNT equivalency expressed in terms of explosive weight to produce the same yield relative to hemispherical TNT.

The test specimens were placed at ground zero in a particular in-plant geometry simulating the manufacturing operations. The test charge was placed on a steel witness plate to provide a consistant surface for all experiments. An explosive booster charge ranging from 1 to 5% of the total explosive weight and a blasting cap were used to initiate the test charge. Blast parameters of the pressure time profile were measured by each of six pressure transducers along each leg of a 90-degree array at selected scaled distances. The selected scaled distances were held constant throughout each set of experiments. The test series were conducted using several different charge weights to provide scalibility of the experiments in several differernt geometries and length to diameter (L/D) ratios.

Individual test programs were predicated upon actual in-process manufacturing operations where improved safety criteria would lessen the probability of a catastrophic event. Details as to exact orientations of the sample material, geometries, confinement, charge weights, booster explosives, booster charge weights, and methods are discussed in detail in each of the individual test reports and in the specific chapter of this document.

TEST MATERIALS

There was a total of 20 explosive materials and three end-items. The high explosives were of the following type: 10 were single compound explosives, all noninitiating type, 6 binary explosives, noninitiating; and 3 primary explosives. The single compound explosives included: Composition A3, Composition A5, Composition C4, HMX, RDX in bulk and slurry, Nitrocellulose, Nitroglycerine, Nitroquanidine, Guanidine Nitrate, and TNT. The binary explosives included: Composition B, LX-14, Cyclotol, Octol, EAK, and PBX. The primary explosives were: Lead Azide, Lead Styphnate, and Tetracene. The explosive end-items included: M42 grenades in a tray of 64, each filled with 30 grams each of Composition A5; M483 ICM 155mm projectile filled with 64, M42 grenades and 24, M46 grenade for a total of 88 submunitions filled with 30 grams each of Composition A5, and the M718/741 Anti-tank Projectile filled with 9 TAAM mines each containing 0.57 kg of high explosive.

A total of 13 propellants and one propelling charges were tested which included: Black powder; Benite; BS-NACO; DIGL-RP; JA-2; M1, M6, M10, M26E1, M30A1, M31A1E1, N5, and WC844. Propelling charges included: XM37, M549 RAP. The propellants were tested in strands, and in single and multiple perforations with and without solvents and propellant waste.

The pyrotechnic mixtures included illuminant mixtures, tracers and igniter mixtures. All of the pyrotechnic mixtures were tested in dry powder form and, in some instances, with simulated manufacturing processes such as pressing or mixing.

TEST CONFIGURATIONS

The test materials were generally placed in in-plant equipment such as storage bins, hoppers, drying beds, thermal dehydration units, transfer bin and carts, shipping containers, or similar equipment. The geometric shapes included orthorhombic, cylinders, cones, truncated prisms, spheres, and hemispheres. The test container construction varied and included aluminum, steel, wood, wood/metal, or cardboard. The containers were either scaled from the original size or tested in full-scale configurations. The test charges were placed at ground zero and initiated by a blasting cap and a booster charge. Blast transducers were placed at ground level in a 90 degree array at predetermined scaled distances generally held constant throughout the experiments even though the charge weights and configurations varied. The geometries, container construction, charge weights, length to diameter ratios, and test areas were variables that could affect the measured values. Care was exercised to standardize or reduce these variables.

TEST AREAS

The test area used for the majority of these experiments was a sand packed runway 6.1 m (20 ft) wide by 91.4 m (300 ft) long by 0.9 m (3 ft) deep. There were two runways 90-degrees apart laid out in a north/south and east/west orientation. Fiducial markers, spaced 3.04 m (10 ft) apart were placed 30.5 m (100 ft) north of ground zero. Cabling to each transducer was buried underground. There were no reflecting surfaces within a radius of 306.7 m (880 ft). A typical test area layout is shown in Figure 1. All even numbered transducers were placed in the north/south gage line and the odd numbered transducers were positioned on the east/west gage line. A minimum of six scaled distances were used for each test series.

Test surfaces varied considerably among the experiments. The test surfaces varied from prairie floor consisting of soft silts and fine sands, to desert floor consisting of sand and clay, to concrete runways, plywood runways, and sand-filled runways on sandy loam and clay. Each of the varying surfaces would have contributed to or have an effect on the experiment; therefore, a steel witness plate was used to standardize the initial reflecting surface. The witness plate was constructed from cold-rolled carbon steel, usually 1015 ranging from a minimum thickness of 12.7 mm (0.5 inch) to a maximum of 25.4 mm (1.0 inch). The length and width was varied for each experiment based upon the test configuration, and was at least 50.8 mm (2 inch) wider and longer than the test container. This is shown in Figure 2. The test material was positioned directly atop the witness plate or on a standoff, varying from 24.4 mm to 152 mm (1 -6 inches). In either case, the standard reflecting surface was achieved. Figures 3 and 4 show other typical test areas.

BOOSTER CHARGE

Initiation of the sample material was standardized by using a booster charge in an explosive train to assure detonation of the test charge. The booster charge was required because of the large diameter of the main charge that, in some instances, exceeded 0.91 m (3 ft). A typical explosive train is shown in Figure 5. Generally, the booster charge was Composition C4, a noninitiating, plastic high explosive that may be configured to fit the experiment. However, other explosives were used as boosters. Typically, the booster was conical-shaped, with the height to diameter ratio held constant at 1:2. Figure 6 shows a typical booster charge configuration. The booster charge was also configured as a cylinder. Generally, in the cylindrical configuration the height to diamete ratio was 1:1. The booster was placed atop or embedded in the main explosive charge. Figures 7 and 8 show typical placement of the booster charge. Although explosive trains are not present in the manufacturing operation, the booster charge was necessary to assure that a detonation occurred. The effect of initiation source had little or no contribution because the booster charge was factored out of the actual calculations.

Initiation of the booster was accomplished by using either a J2 engineers' special blasting cap or a number 8 strength cap. The initiator was embedded in the apex of the cone or into the cylinder.

TEST GEOMETRIES

Airblast output was evaluated for weights and configurations representative of in-plant, in-process configurations, storage containers, and standard shipping containers. Explosives were also cast in spheres and hemispheres for controlled experiments.

Orthorhombic containers were used to simulate conveyor buckets, nutsche containers, dryer beds and standard shipping containers. The length to diameter ratio was usually less than 1:1. The containers were constructed from wood, as in wire-bound shipping boxes, steel or aluminum, simulating nutsches containers and conveyor buckets, and fiberboard two-piece telescoping shipping containers. Figure 9 shows typical orthorhombic containers used in the experiments and the placement of the booster charge.

A second type of orthorhombic container was used in which the height to diameter ratio was greater than 1:1. The containers were constructed from steel, wood with either a zinc or copper liner, plywood, or fiberboard. These types of containers which were usually shipping containers, are shown in Figure 10.

Dryer beds were constructed from plywood to simulate dryers found in in-plant configurations. The height to diameter ratios were usually less than 0.1:1. Figure 11 shows a typical dryer bed configuration.

Cylindrical containers were constructed from fiberboard, steel, plastic, and glass and were used in simulatation of many other in-plant conditions besides shipping containers. These cylinders were sometimes scaled or tested in full-scale configurations. Figures 12, 13, 14, 15, and 16 show the typical cylindrical configurations tested. The height to diameter ratios were usually equal to or greater than 1:1.

Truncated prisms were used to simulate hoppers and other types of transfer bins. They were constructed from plywood, aluminum and steel. The height to diameter ratios were usually equal to or greater than 1:1. Typical configurations are shown in Figures 17, 18, 19, and 20. Other orthorhombic configurations were employed to simulate specific in-process operations. These included transfer carts constructed from steel or aluminum, blender charging buckets, and drop buggies. Figures 21 and 22 show the transfer carts.

Explosives were tested as cast spheres, hemispheres, pressed billets extruded rod, carpet rolls, single grains, and as a loose powder in bags. Figures 23, 24, 25, 26, 27, 28, 29, and 30 show these configurations. The height to diameter ratio varied greatly.

The test configurations and the various containers had an effect on the measured blast pressure and positive impulse. Higher peak pressures and positive impulse values were obtained when the height to diameter was greater than 1:1. These higher pressures and impulses were most noticable at the near-field scaled distances, while lower peak pressure and impulse values were noticed at the far-field values. When the height to diameter ratio was less than 1:1, lower pressure and impulse values were measured at the near-field scaled distances and higher pressures and impulse values were measured at the far-field scaled distances.

End-item configurations are shown in Figures 31, 32, 33, 34, and 35. The 155 mm projectiles contained submunitions. M42 and M46 grenades were used in the M483 projectile and were used to simulate the in-process conditions at the LAP station where the grenades are readied for for placement into the projectiles. The blast measurements for the M718/741 155 mm projectile were obtained in accordance with DOD EXPLOSIVES HAZARD CLASSIFICATION PROCEDURES, US Army Technical Bulletin 700-2[2]. The test configurations were single rounds, two rounds, and a shipping pallet containing eight projectiles. M1 Propellant and the XM37 RAP propellant were also tested in end-item configurations.

The end-item exterior package was a factor in the measured values as well as the height to diameter ratio. The heavy confinement reduced the pressure and impulse values, and the height to diameter ratio effect was noted in the near-field and far-field measurements.

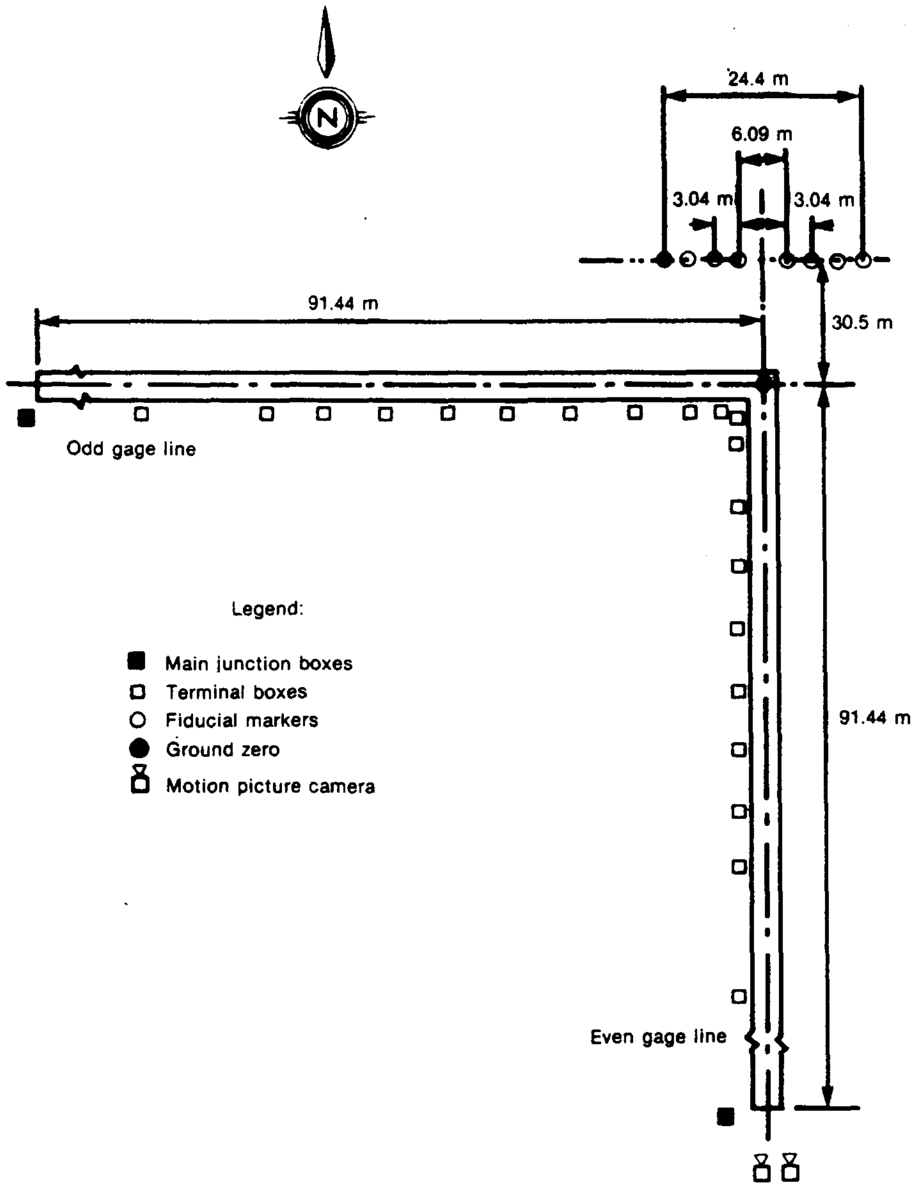


Figure 1. Instrumented Test Pad Layout.

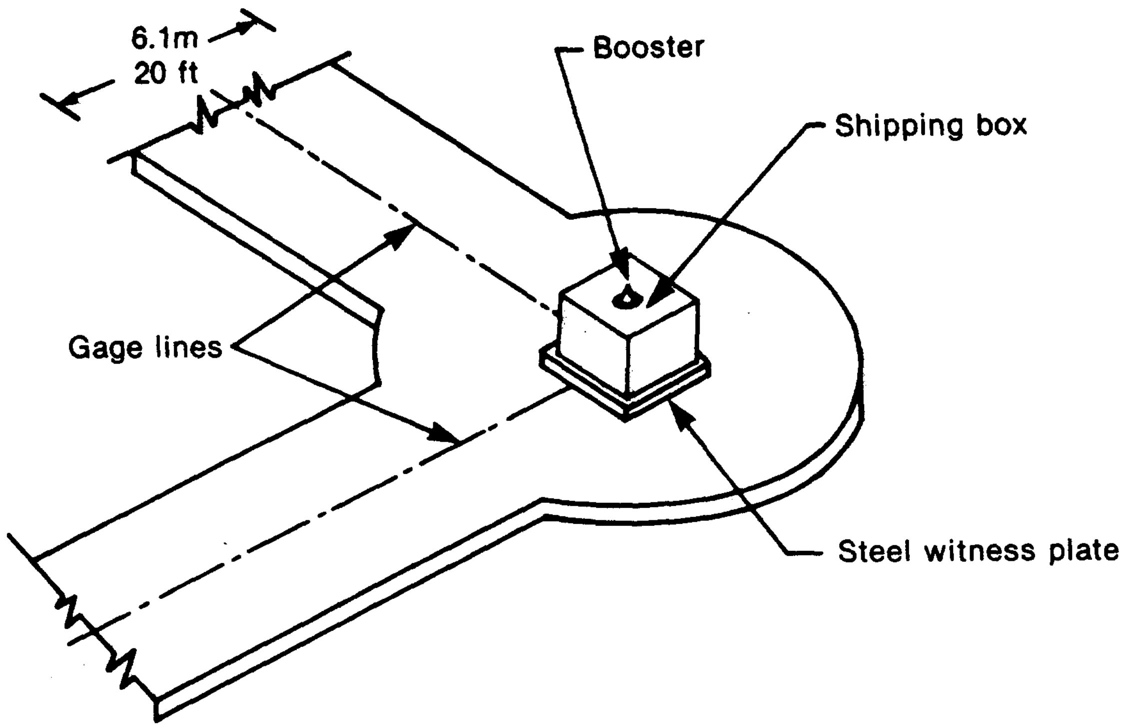


Figure 2. Typical Test Charge Setup on a Steel Witness Plate.

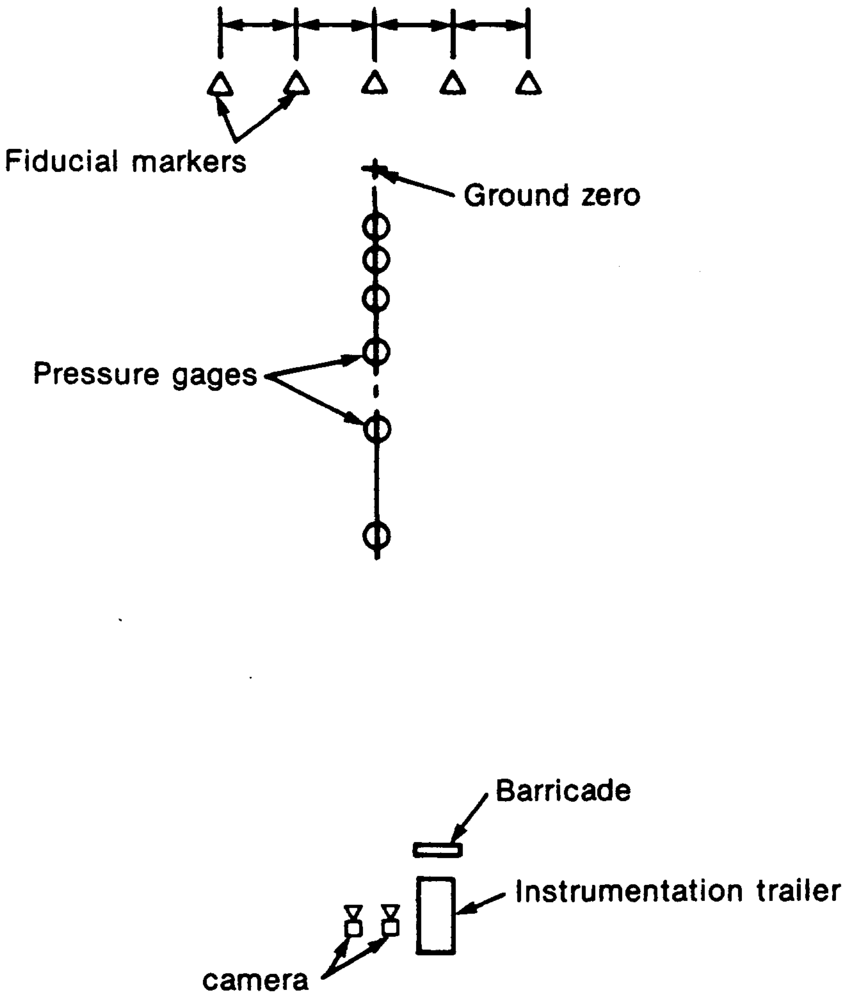


Figure 3. Test Setup for Nitroglycerine Tests.

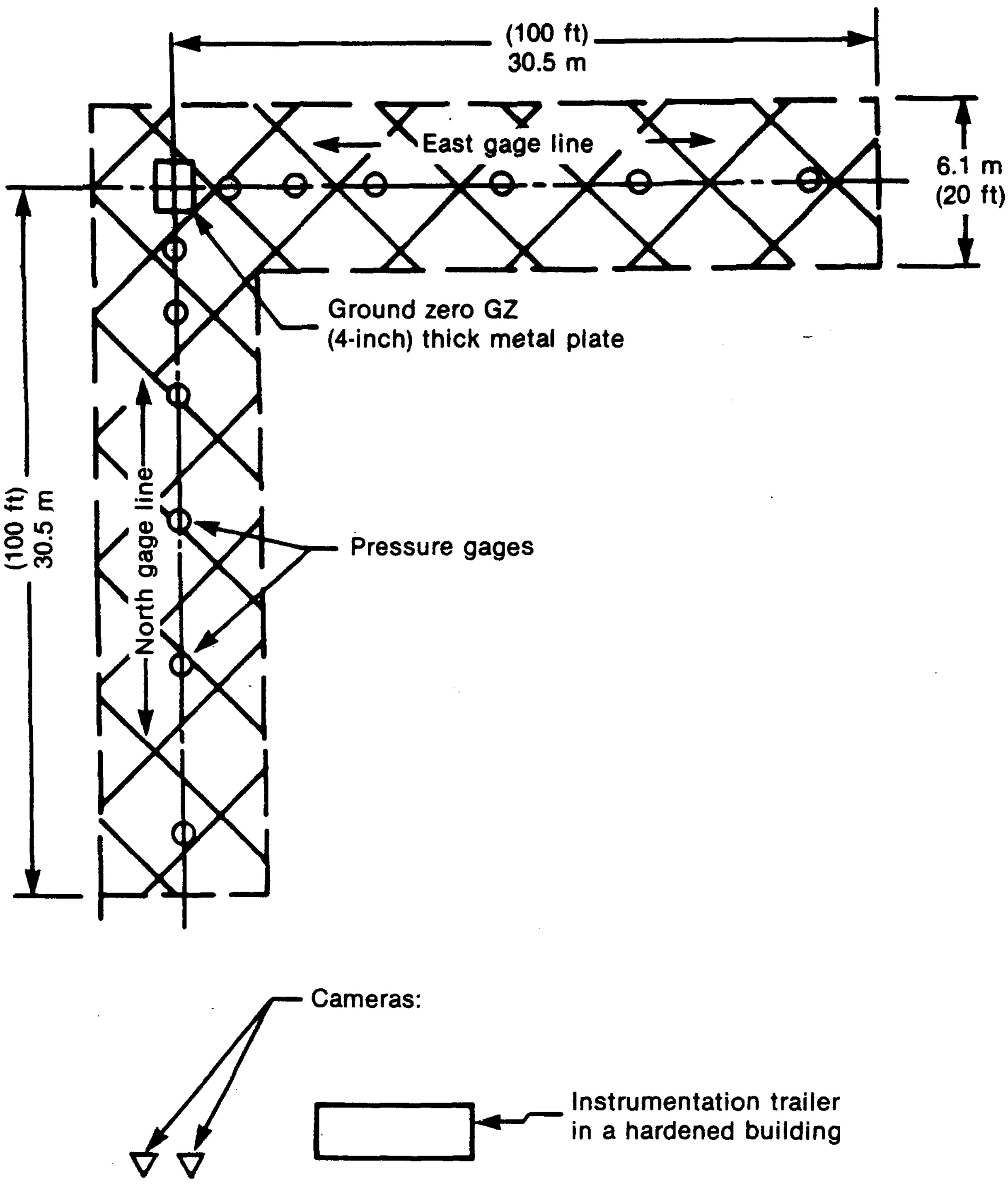


Figure 4. Field Test Setup for Tetracene.

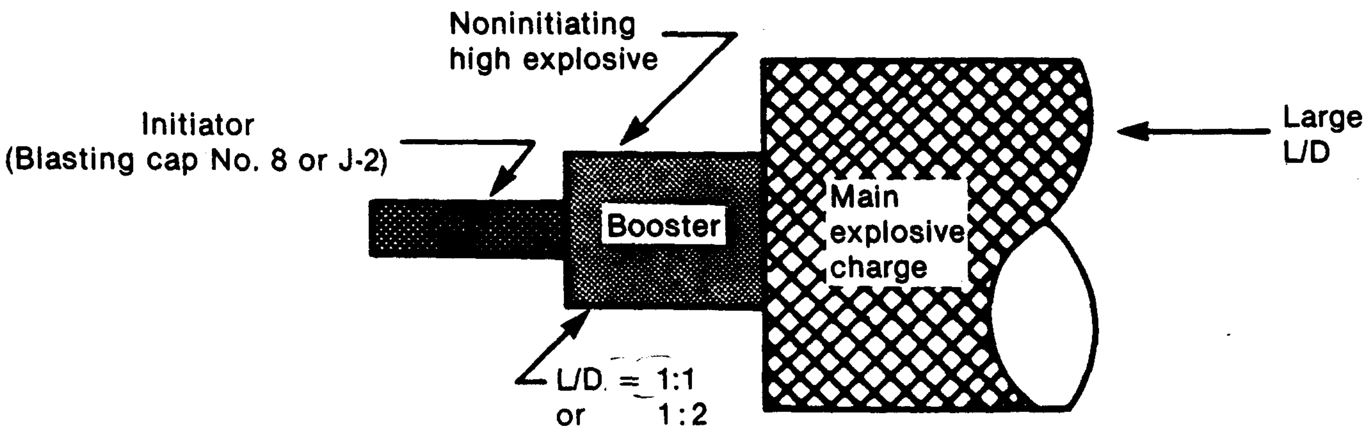


Figure 5. A Simple Explosive Train.

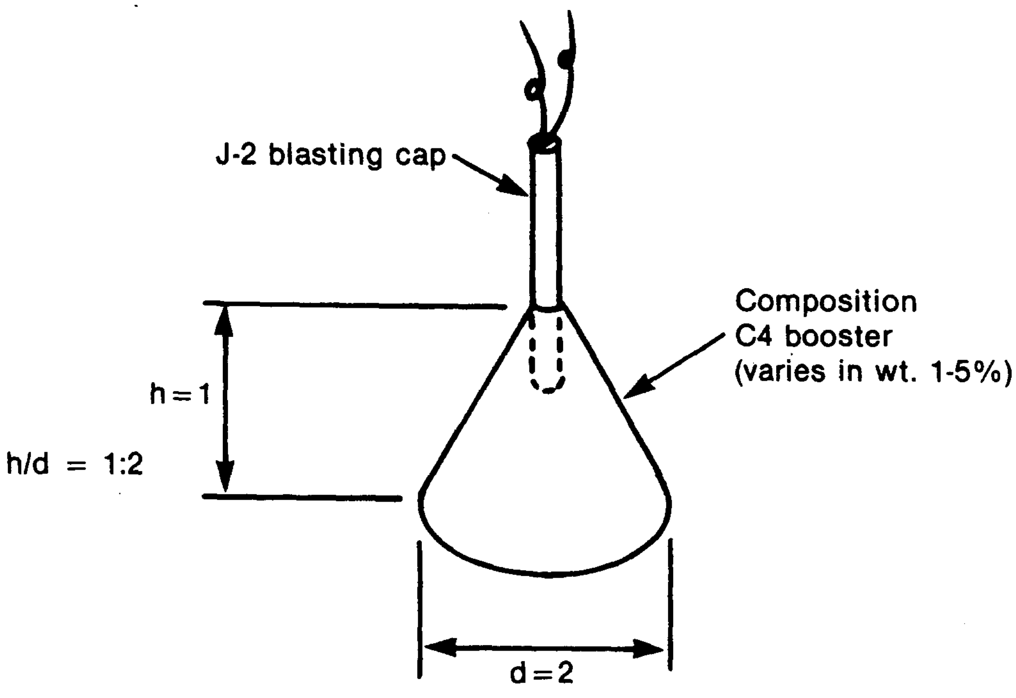


Figure 6. Typical Booster Charge Configuration.

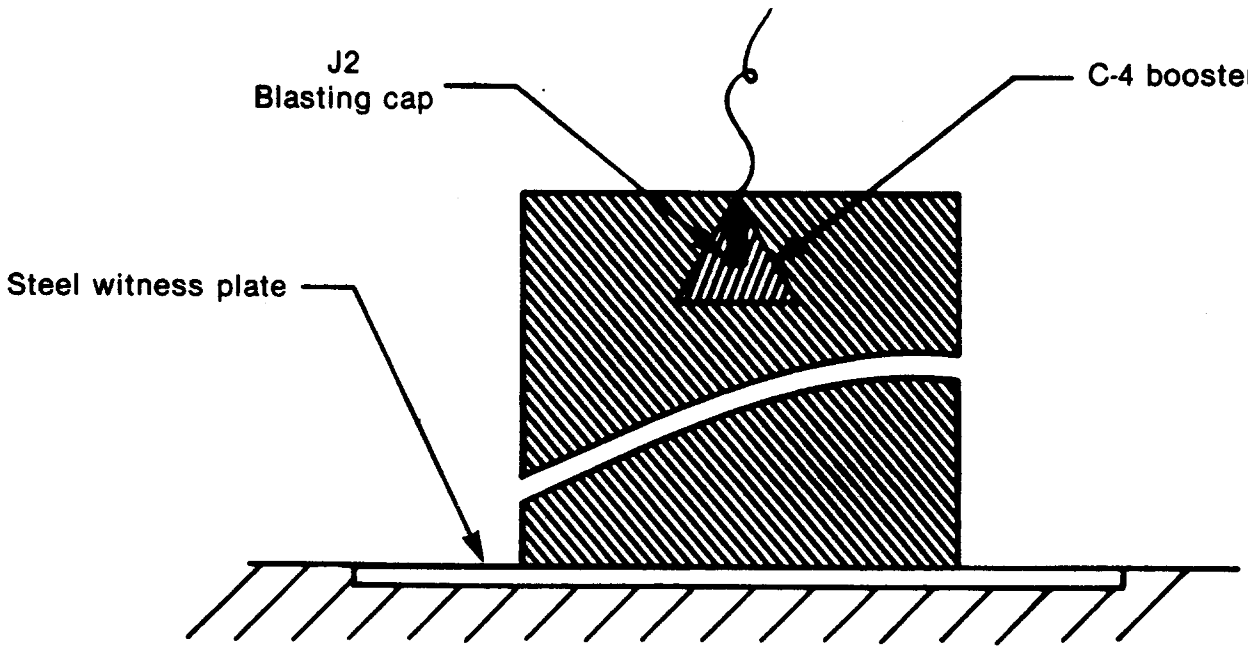


Figure 7. Conical-shaped Booster Charge Imbedded in Sample Material.

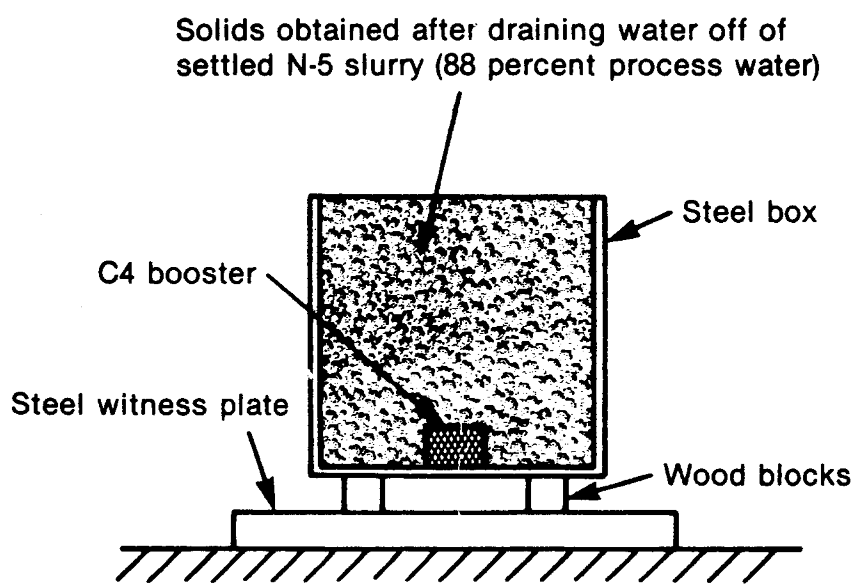


Figure 8. Cylindrical Booster Charge Placement.

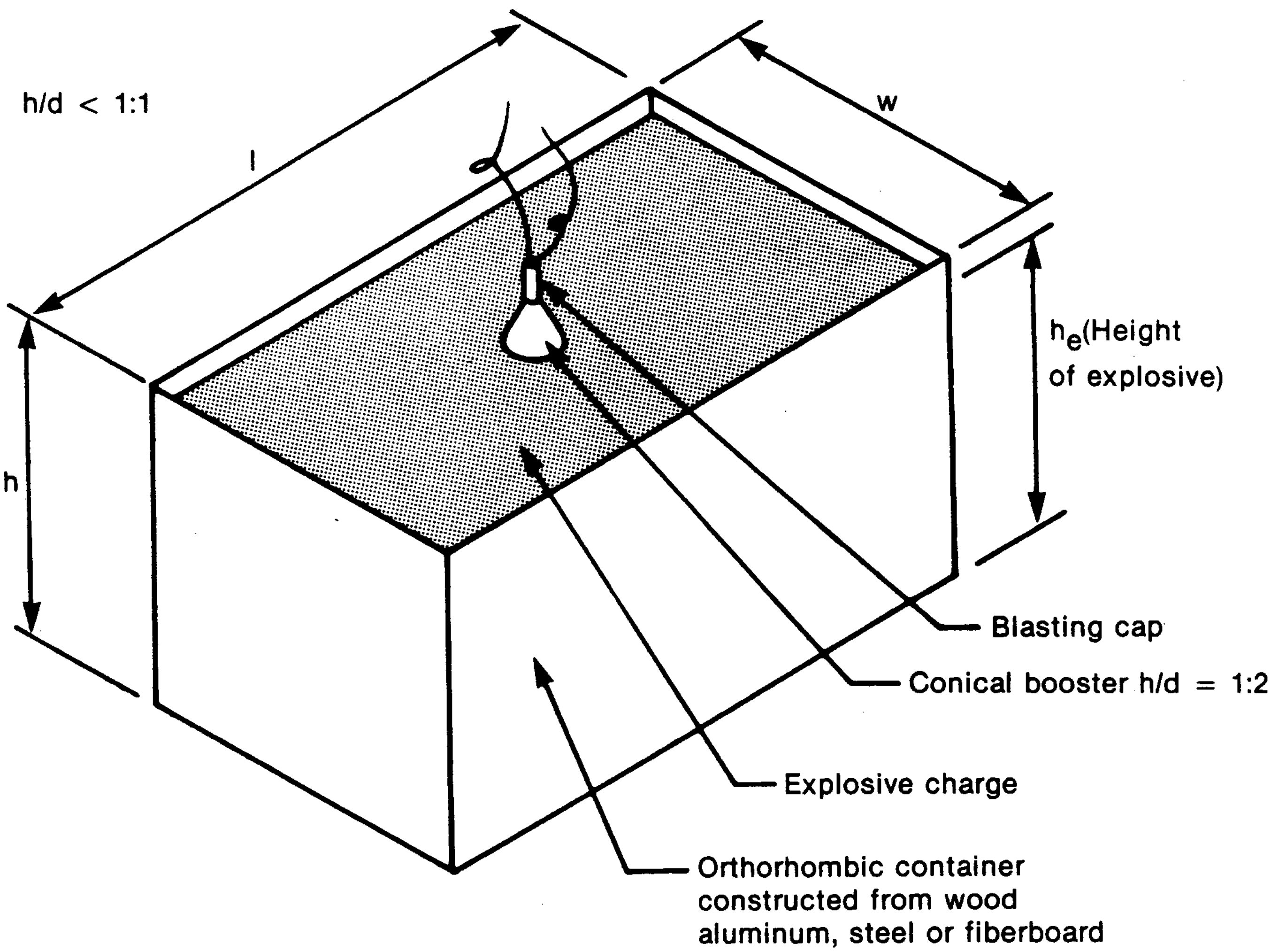


Figure 9. Orthorhombic Container.

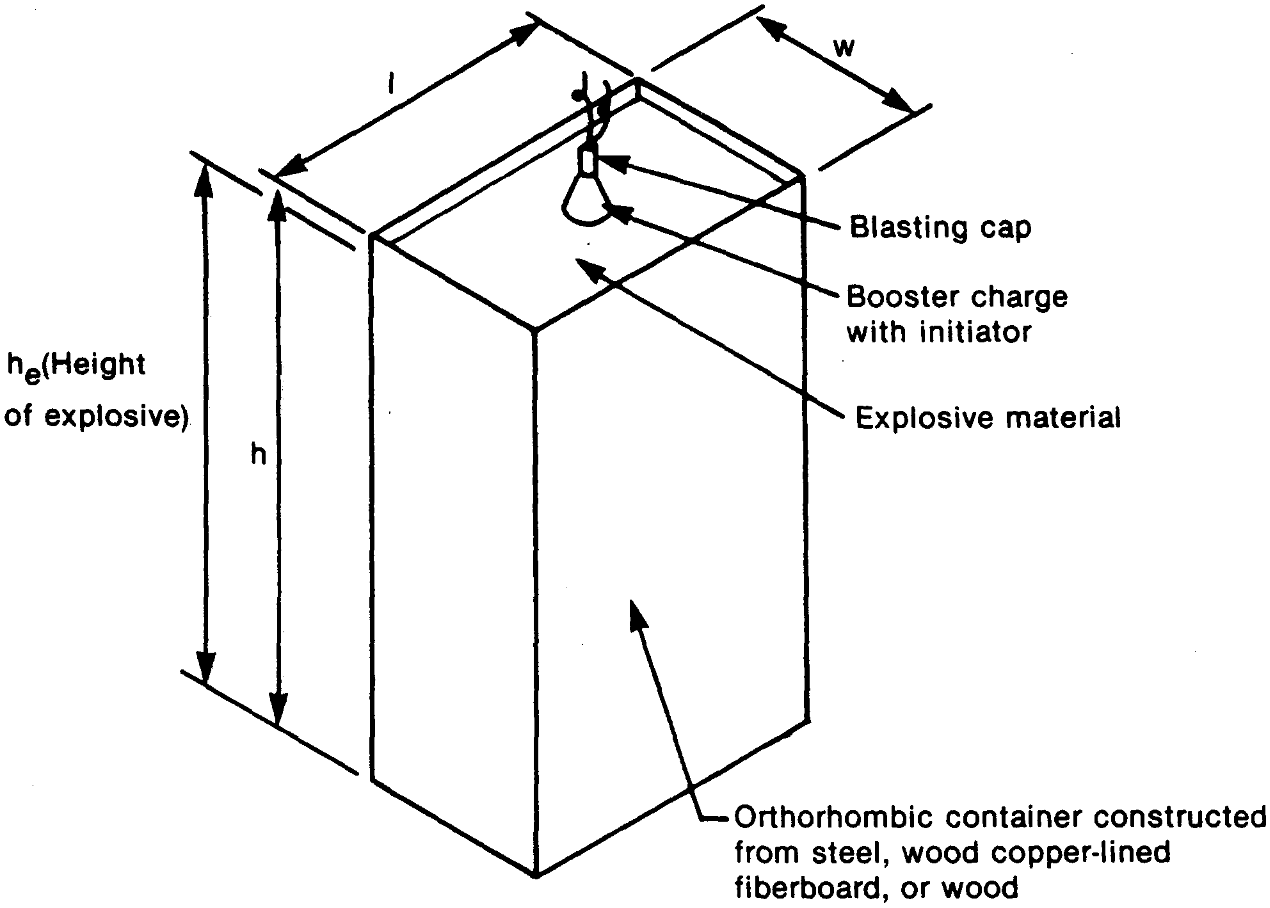


Figure 10. Orthorhombic Container with L/D Ratio >1:1.

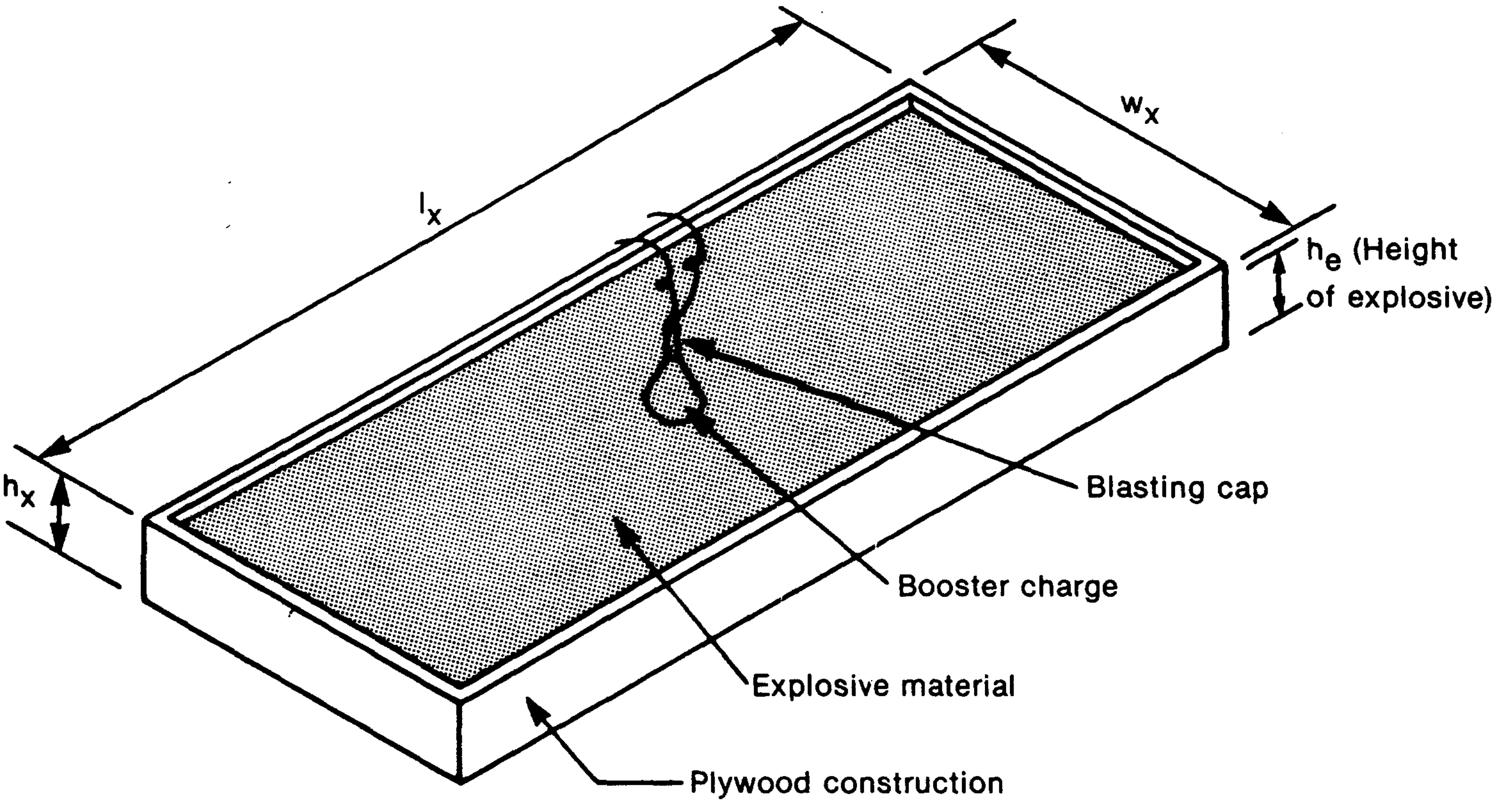


Figure 11. Orthorhombic Container as a Dryer Bed.

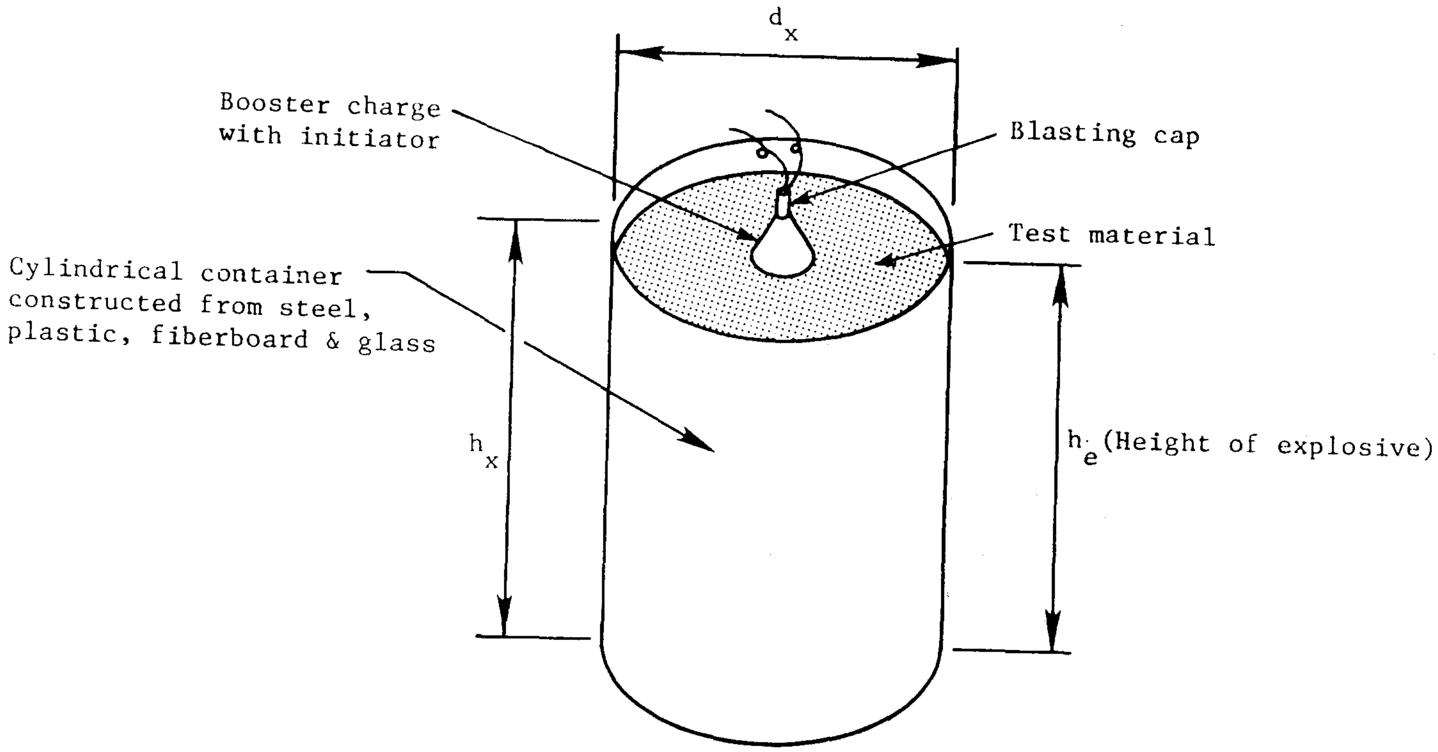


Figure 12. Typical Cylindrical Container Test Configuration.

(d) <u>Encased RDX Slurry Charges</u>

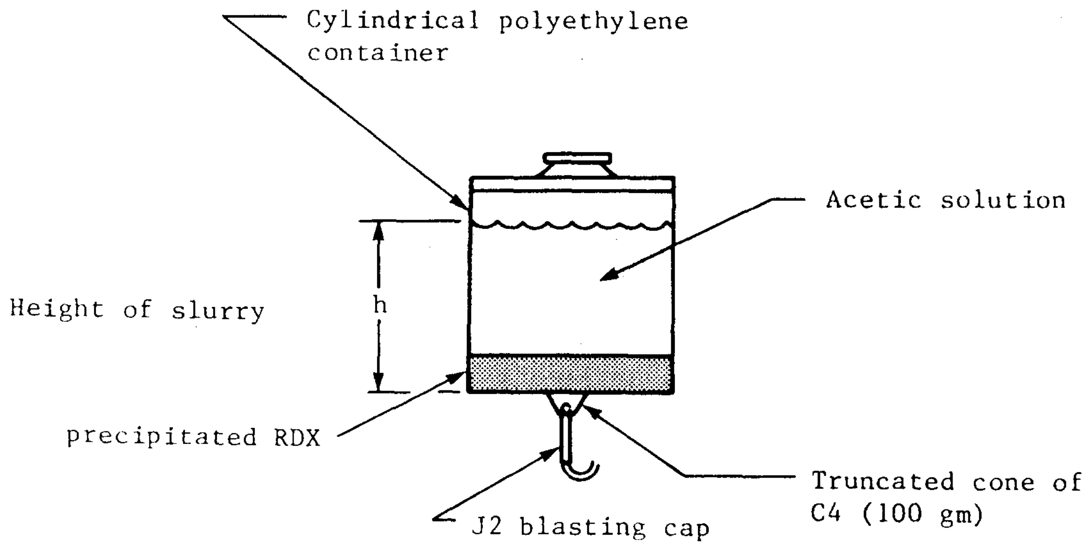


Figure 13. Typical Test Setup for RDX Slurry.

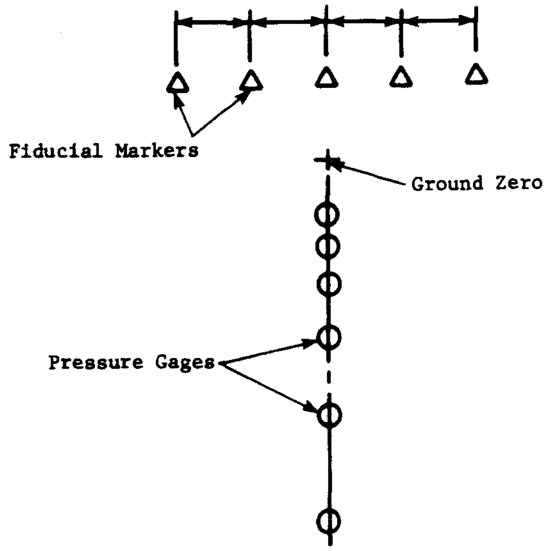


Figure 14. Typical Nitroglycerine Test Setup.

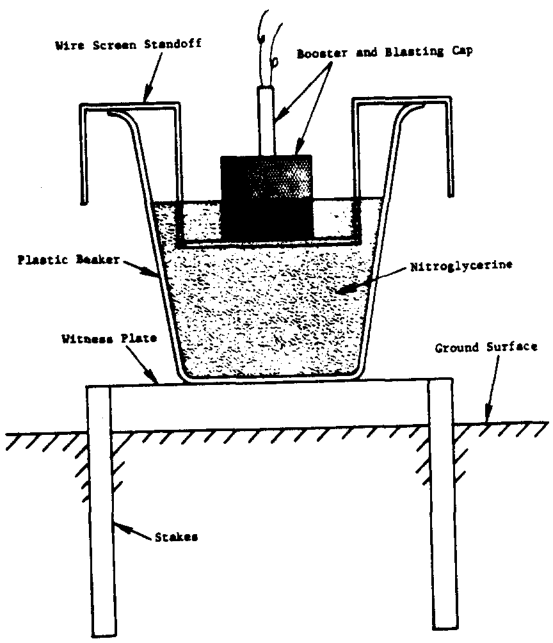


Figure 15. Beaker Test Configuration.

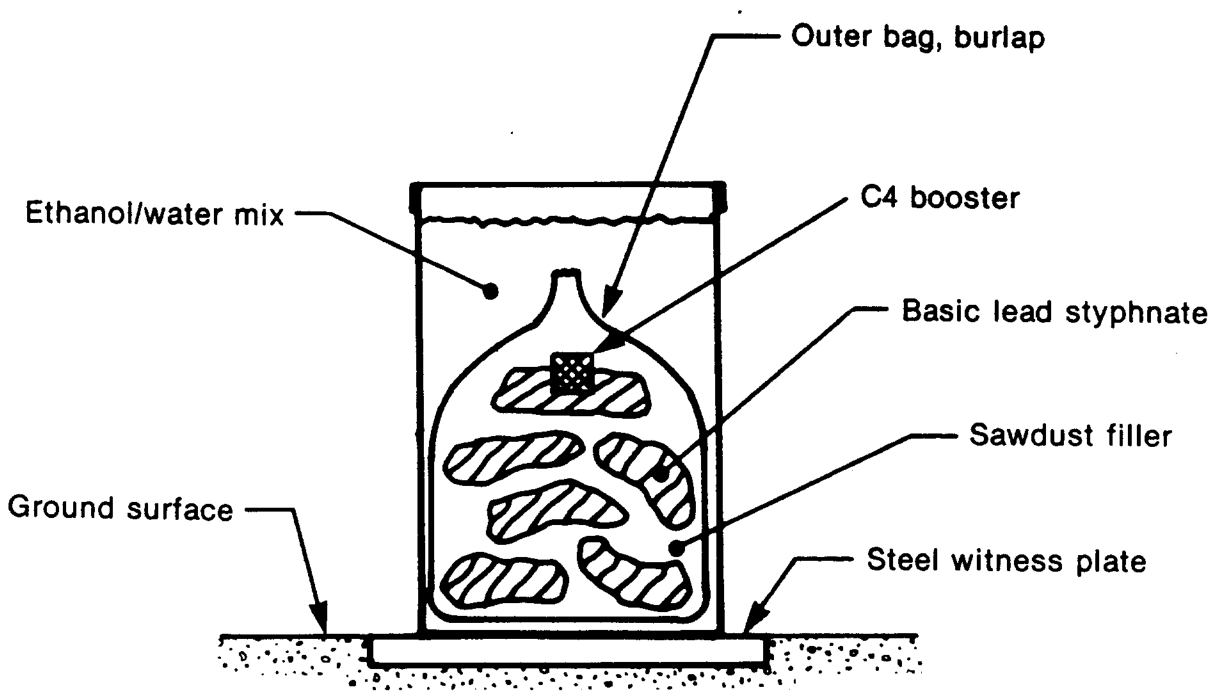


Figure 16. Basic Lead Styphnate Test Setup.

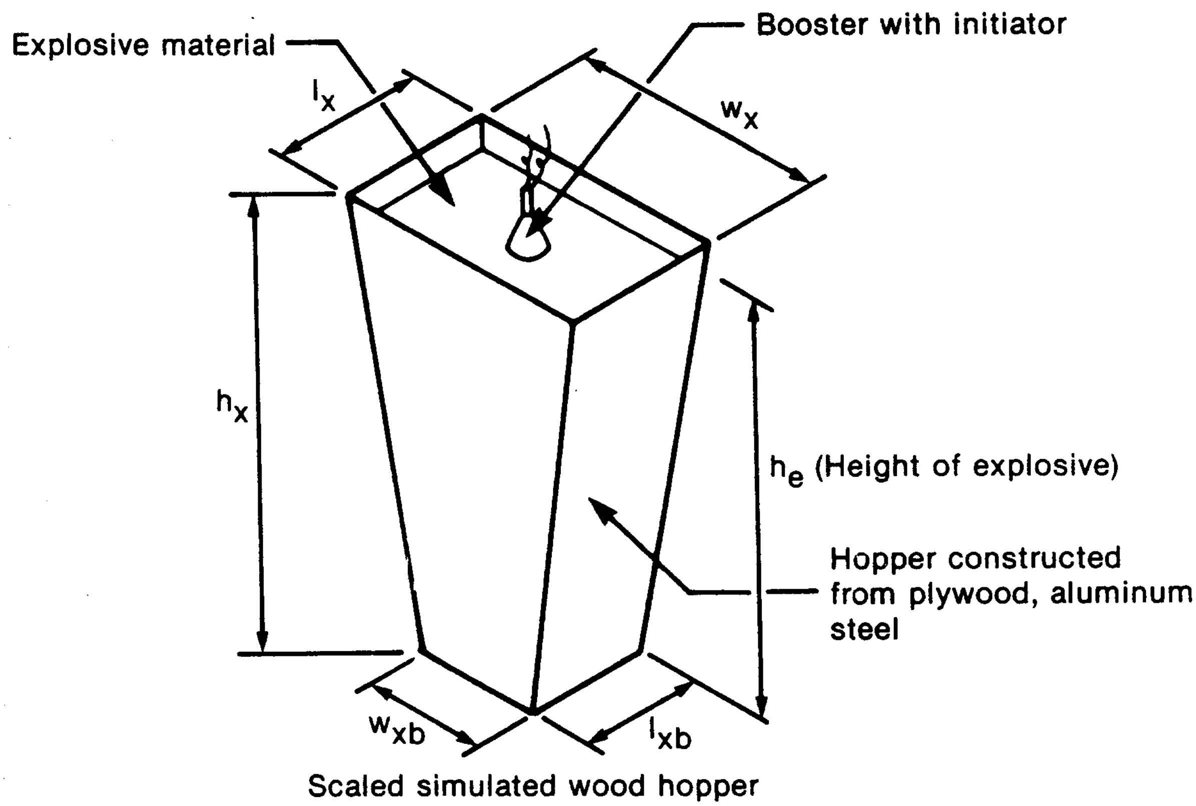


Figure 17. Truncated Prism Simulating a Typical Hopper Test.

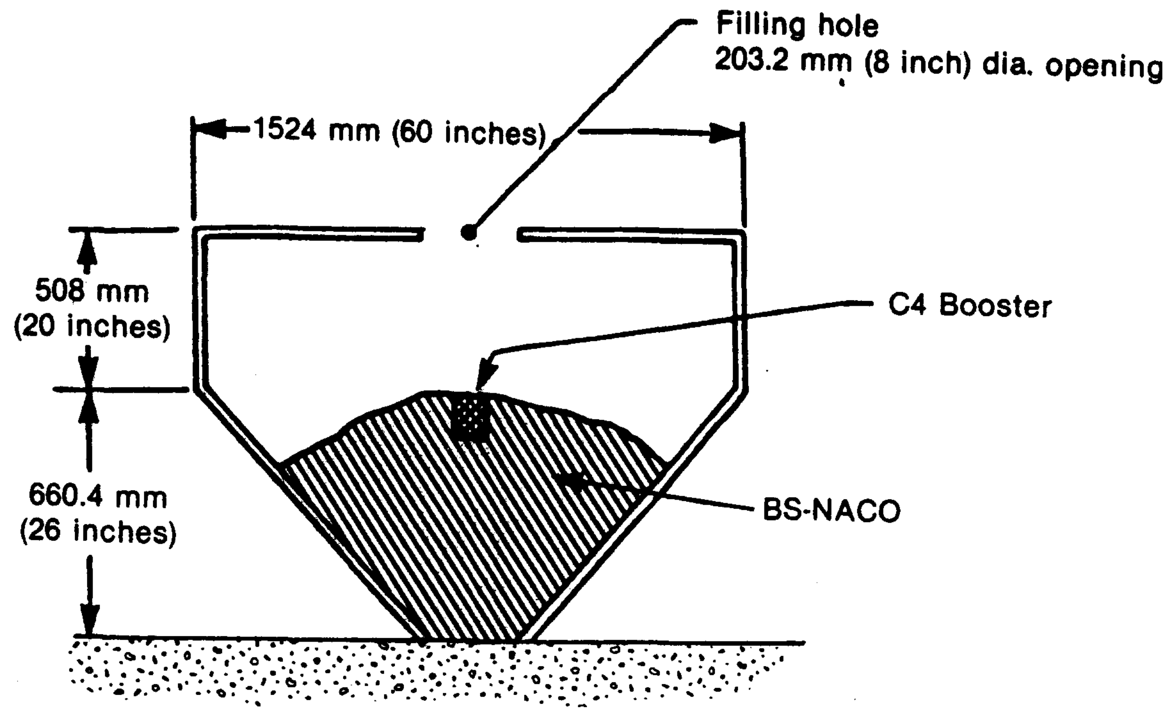
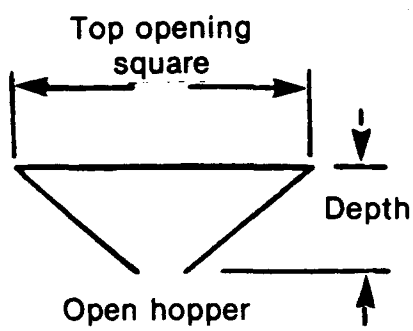


Figure 18. Feed Hopper Test Configuration.

Load	Depth	x	Top opening
22.7 kg (50 lb)	259 mm (10.2 inches)	x	876 mm (34.5 inches)



Load	D	L	H
22.7 kg (50 lb)	892 mm (35.1 inches)	290 mm (11.4 inches)	386 mm (15.2 inches)
11.3 kg (25 lb)	709 mm (27.9 inches)	231 mm (9.1 inches)	307 mm (12.1 inches)
5.44 kg (12 lb)	554 mm (21.8 inches)	180 mm (7.1 inches)	241 mm (9.5 inches)
2.72 kg (6 lb)	439 mm (17.3 inches)	142 mm (5.6 inches)	191 mm (7.5 inches)

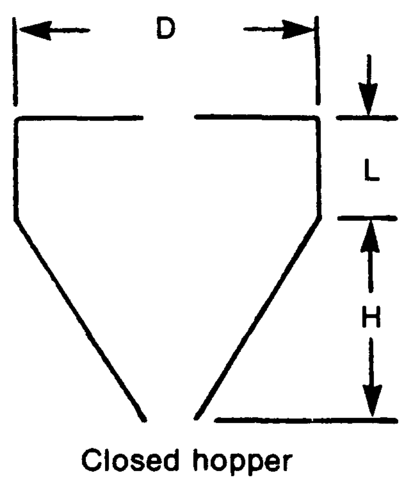
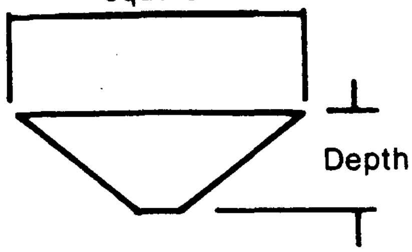


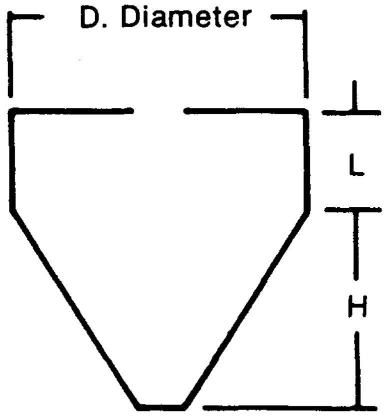
Figure 19. Typical Hopper Used in Propellant Test.

Nominal Load	Depth x Top Opening
Normal Load	Full Scale Size
130 lb SP	12 x 42 Square
50 lb SP	8.7 x 30.5 Square
Normal Load	Full Scale Size
190 lb MP	16 x 54 Square
50 lb MP	10.2 x 34.5 Square



Indiana AAP
open top hopper

Nominal Load	D	L	H
Normal Load	Full Scale Size		
250 lb SP	60.0	19.5	26.0
50 lb SP	35.1	11.4	15.2
25 lb SP	27.9	9.1	12.1
12 lb SP	21.8	7.1	9.5
6 lb SP	17.3	5.6	7.5
Normal Load	Full Scale Size		
303 lb MP	60.0	19.5	26.0
50 lb MP	35.1	11.4	15.2



Radford AAP
closed top hopper

Figure 20. Typical Propellant Hopper Tests.

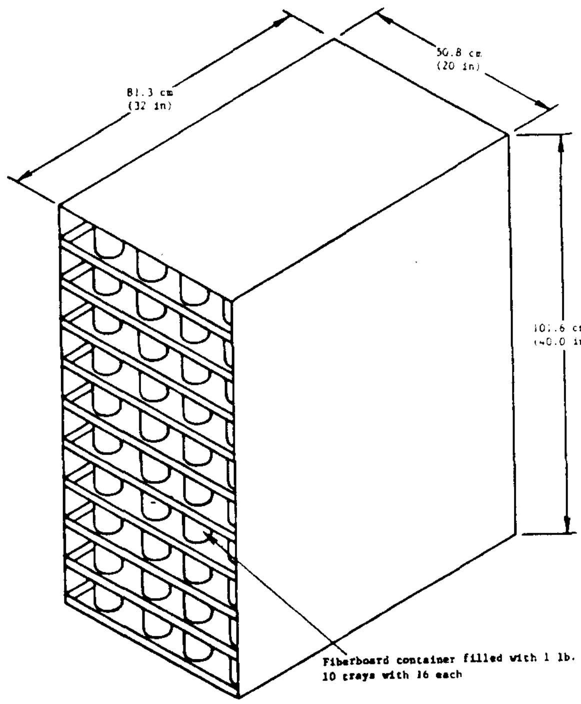


Figure 21. Aluminum Transfer Cart with Bulk Explosives.

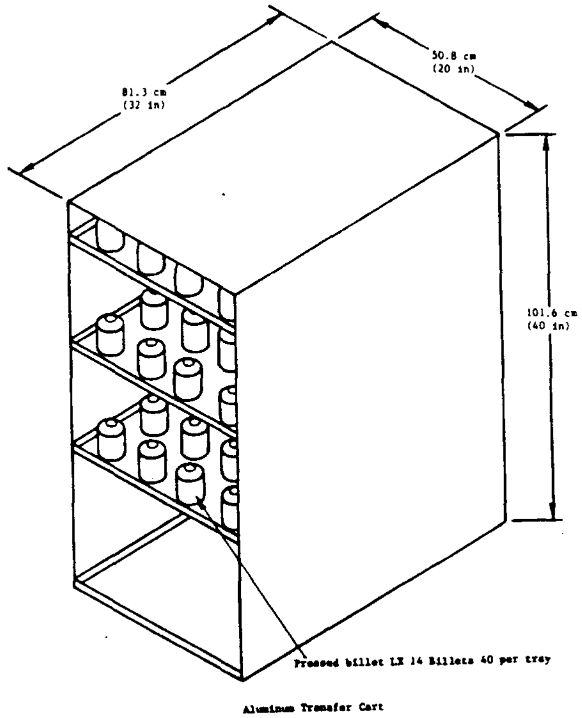


Figure 22. Aluminum Transfer Cart Test for Pressed Billets.

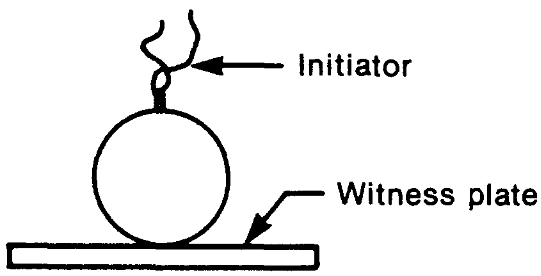


Figure 23. Cast Sphere Test Configuration

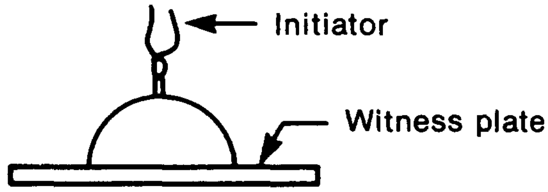


Figure 24. Typical Hemisphere Test Configuration.

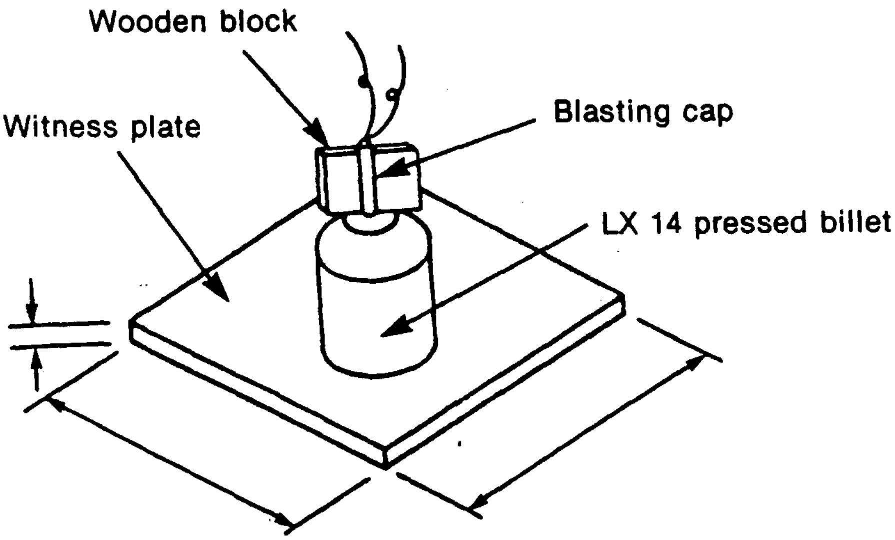


Figure 25. Typical Pressed Billet Configuration.

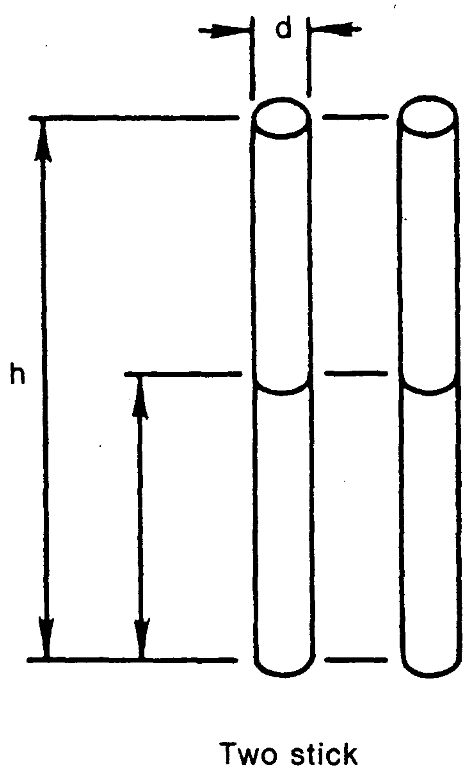


Figure 26. Simulated Extrusion Press Die Configuration.

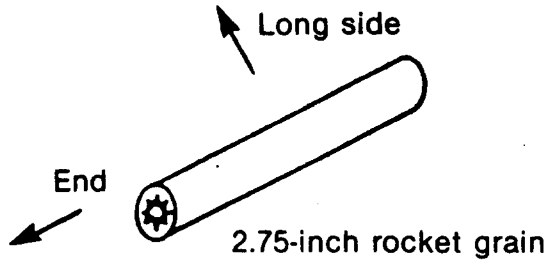


Figure 27. Typical Propellant Grain Test Configuration.

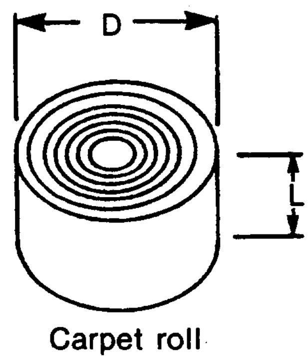


Figure 28. Typical Carpet Roll Test Configuration.

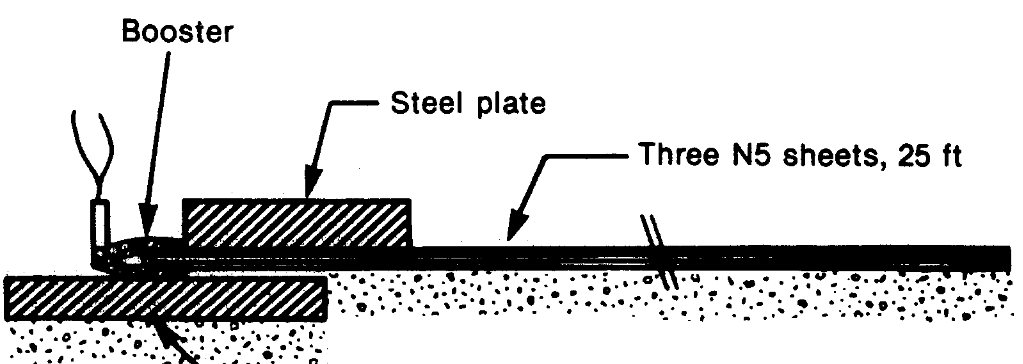


Figure 29. Typical Propellant Sheet Test Configuration.

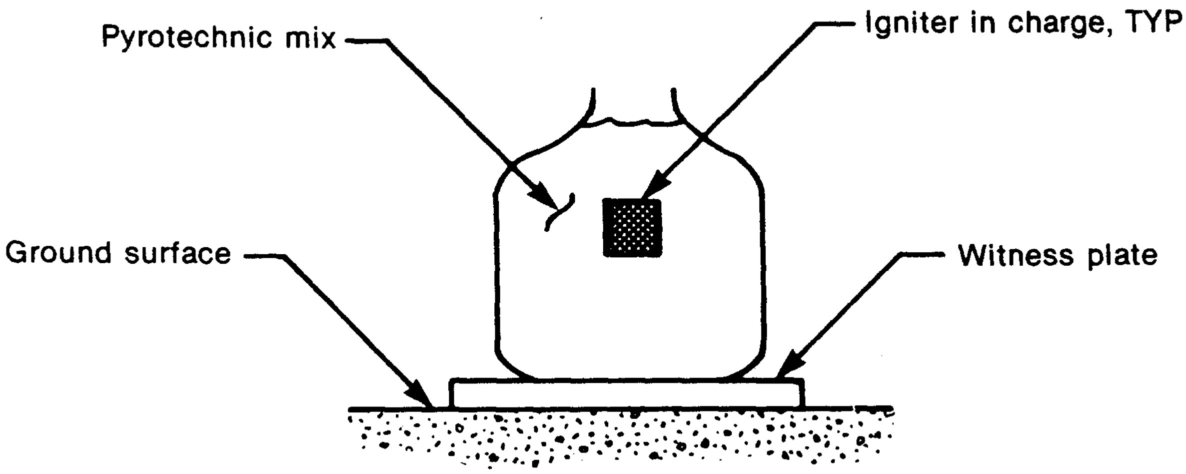


Figure 30. Typical Bag Test Configuration .

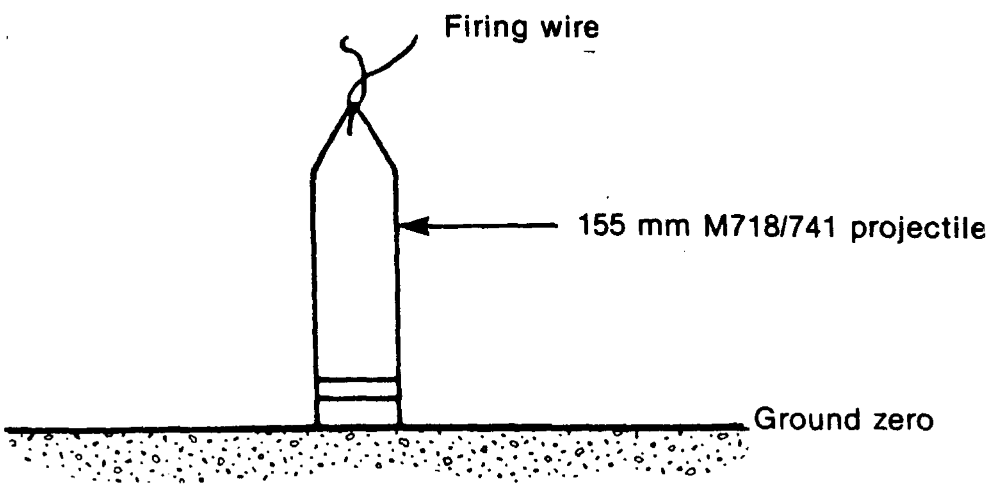


Figure 31. Single Round Test Setup.

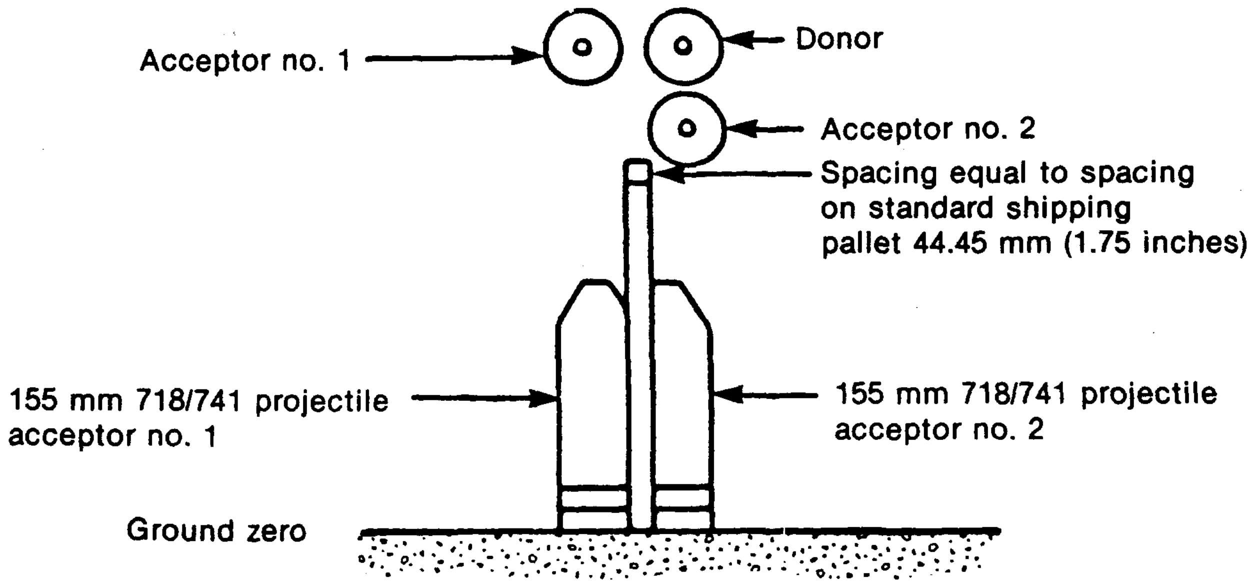


Figure 32. Three Round Test Configuration.

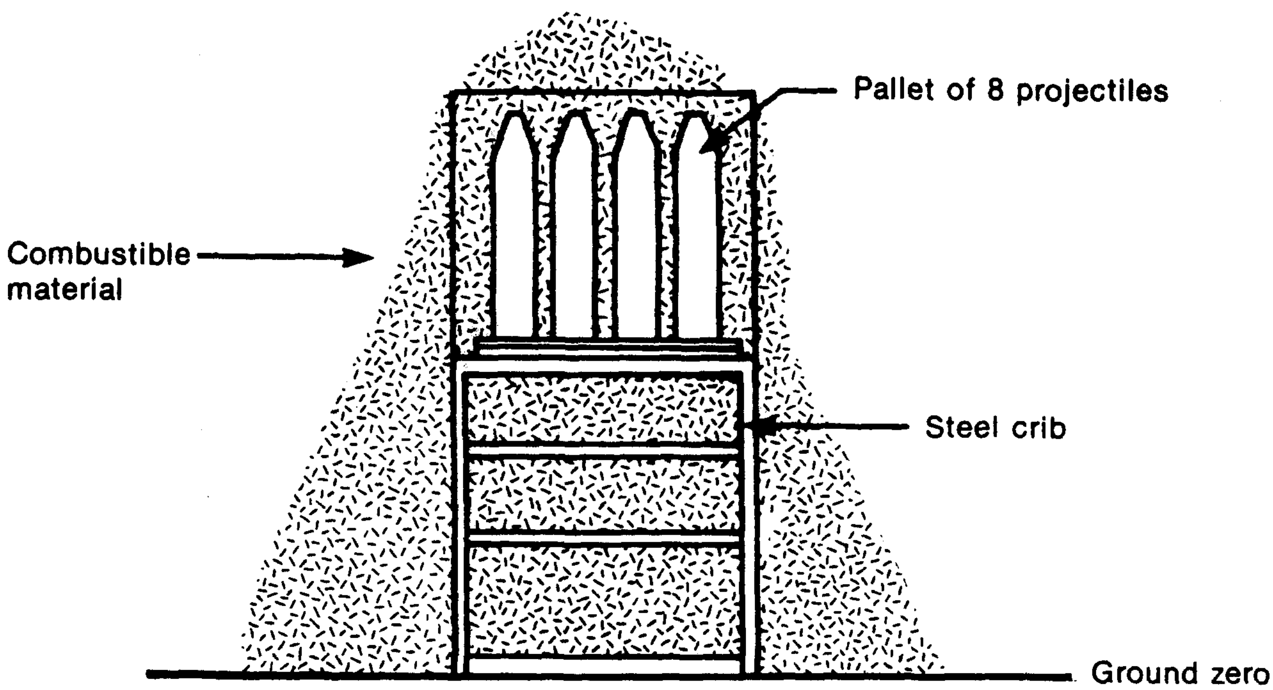


Figure 33. External Fire, Stack Test Configuration.

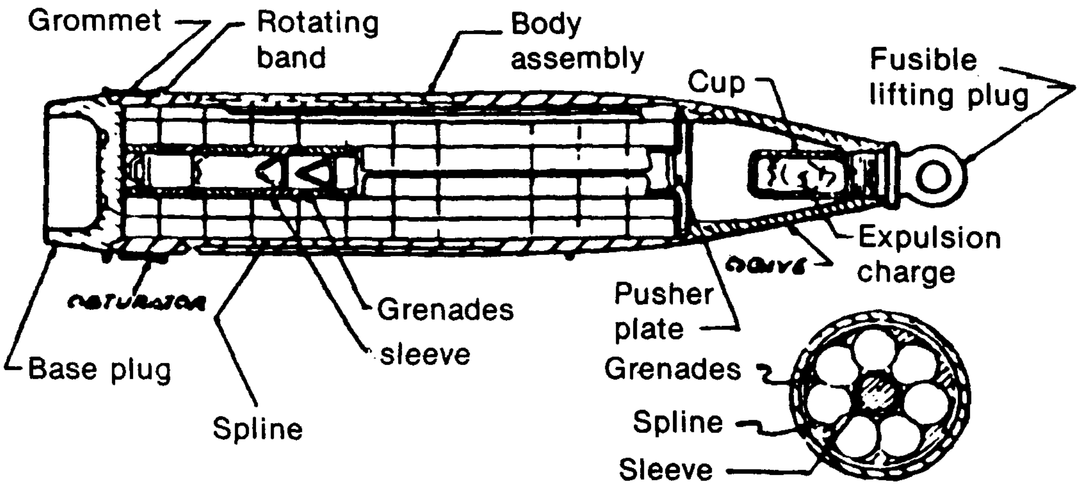


Figure 34. 155mm M483 Projectile.

PROJECTILE, 155MM, AT, M718/741

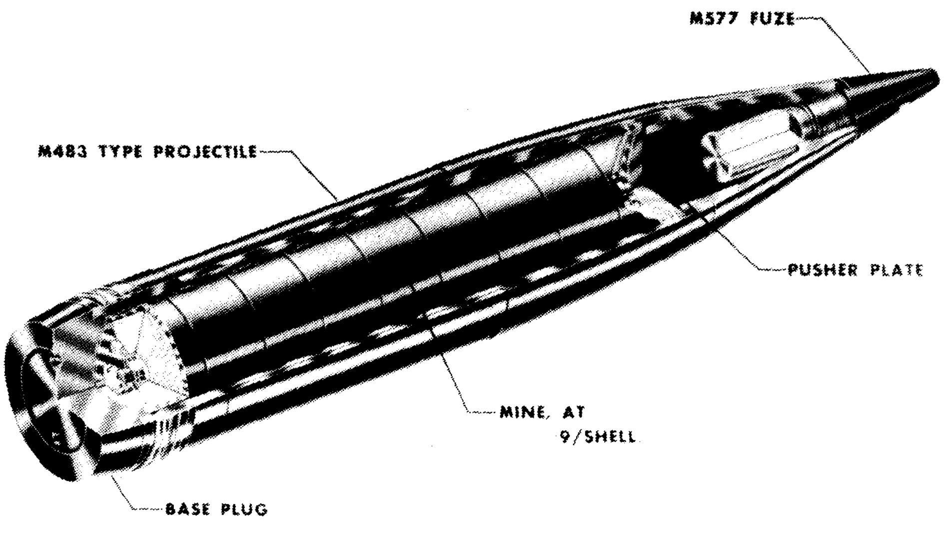


Figure 35. 155mm M718/741 Projectile.

INSTRUMENTATION

BACKGROUND

TNT equivalency is defined as the weight of a TNT explosive charge which produces the same peak pressure or ratio of impulse-to-distance at a given distance as that produced by the material under test[2].

The ratio of peak pressure and impulse are determined by the measurement of the blast pressure profile. These measured parameters include: peak pressure (P_s), the maximum overpressure which occurs at the instant of the pulse arrival; positive duration (t_+), the interval between shock front arrival and the time at which the overpressure returns to zero; negative phase duration (t_-), the interval where the pressure decays below ambient to a partial pressure and then returns to ambient; time of arrival (T_A), the time for the blastwave to arrive at a given distance from ground zero; and positive Impulse (I_s), the interval of the overpressure from the time of the shock arrival to the end of the positive phase. Generally, only the peak pressure, positive impulse, time of arrival and the positive duration are measured and reported.

Measurement of these values required the latest state-of-the-art techniques and equipment. An elemental data acquisition system consists of transducers, cabling to couple the transducer to signal conditioning equipment, signal conditioning equipment, and an appropriate recording system. Each component of the Data Acquisition System is critical for the measurement of the blastwave. The transducer converts the blastwave energy into an electrical signal, the cabling pass the signal without distortion or attenuation, the signal conditioning device amplifies or attenuates the signal and the recording system captures and stores the signal. All of the components must have good impedance matching and the system error of each componet should be minimized so that total overall system error is less than 2%.

Ideally, the pressure transducer should have characteristics of infinite frequency response, be small in size, offer no disturbance to the shock front, be sensitive only to blast parameters, have a large signal output from a small input, be linear throughout the entire pressure range and have excellent stability. In reality, such transducers do not exist. However, piezoelectric transducers offer excellent characteristics with few compromises. These types of transducers are linear over an extremely wide range, have a very high frequency response, are stable, mechanically strong, are able to survive considerable punishment, provide a large signal output from a small input, small in size, and can be designed so that they offer no disturbance to the shock front.

The coaxial cabling couples the transducer output to the signal conditioning equipment. Coaxial cabling has a high impedance, making the transmission line seem infinitely long. Coaxial cabling has a nominal capacitance of 28 x 10^{-12} Farad/ft. Coaxial cabling offers no distortion during the transmission of the signal and a nominal amount of attenuation.

Signal conditioning equipment must be compatible with the pressure transducer and the recording system. Signal conditioners should have high impedance equal to or greater than the the transducer, and should have good fidelity and provide the necessary gain or attenuation of the signal for proper coupling to the recording system. The most important single atribute of a signal conditioning device is that it has good fidelity so that it can pass the blast signal with no distortion.

Recorders used for blast measurement must be capable of capturing multiple signals simultaneously; store raw data; provide playback capabilities for a permanent record; have good impedance matching with the signal conditioner; provide for a high degree of accuracy, precision, and resolution; and be easily calibrated. Recorders may be either digital, such as digital oscilloscopes, digital transient recorders, and digital tape recorders; or analog recording devices such as oscillographs, oscilloscopes, and magnetic tape recorders. The output from all of these types of recorders may be either digital or analog.

SYSTEM DESCRIPTIONS

The data reported were obtained using components similar to those described above. The compiled TNT equivalency data were acquired by four different test agencies. Each agency utilized different data acquistion systems that best measured and captured the blast pressure profile. Although different components were used by each agency, the achieved results represent a good cross section of the current state-of-the-art measuring techniques. A cursory synopsis of each of the different system is given.

IITRI System

The pressure measuring system employed by IITRI was Photocon model 752A pressure transducer, Photocon DG605D Dynagage, Hewlett-Packard 8875A dc amplifier, Tektronix type O operational amplifier, Tektronix Model 122 amplifier, Ampex model AR-200, and Ampex model CP-100 magnetic tape recorders, CEC 1-172 drive amplifiers and a CEC model 5-124 Oscillograph recorder. Each of the major components are described below.

The Photocon Model 752A has a dynamic range of 0 to 34.5, 345, or 1379 kPa (0 to 5, 50, or 200 psi) with a frequency response of 0 to 10 kHz. The diaphragm of the transducer, in conjunction with an insulated stationary electrode, forms a capacitor. The pressure wave flexes the diaphragm causing a change in capacitance proportional to the applied pressure. The transducer capacitance and a built-in inductance form a tuned radio frequency (RF) circuit. The tuned circuit is coupled by a low impedance cable to the dynagage. The dynagage system consists of an oscillator-dector circuit and a cathode-follower amplifier. The changes in capacitance produce a change in the diode detector impedance, producing an output signal voltage proportional to the applied pressure. The output from the dynagage is coupled to a Hewlett-Packard (HP) Model 8875 differential amplifier. The output from the amplifier is coupled to an Ampex model AR-200 magnetic tape recorder and to a Tektronix type O operational amplifier for impulse integration.

Data were recorded using two magnetic tape recorders-an Ampex model CP-100 and an Ampex model AR-200. The Ampex model CP-100 was the primary recorder and the Ampex model AR-200 was used as the backup. The recording levels for the model AR-200 were adjusted to the signal levels one-fifth of the anticipated fill-scale values. The recording format was the same for both recorders: 13 FM recording tracks and a single direct recording channel for the time base signal. Data recorded on the model AR-200 were reproduced on the model CP-100, when required. The blast pressure data were recorded an a speed of 1524 mm/s (60 ips) and reproduced at a tape speed of 47.6 mm/s (1-7/8 ips).

Data from the recorders were outputed to a CEC type 1-172 driver amplifier to drive a CEC type 7-363 galvanometers on a CEC Model 5-124 recording oscilosgraph. The oscillograph speed was 812.8 mm/s (32 ips). This represents a horizontal resolution of 976 s/inch and an effective frequency response from dc to 20 kHz, referred to real time.

Figure 36 represents a block diagram of the typical instrumentation system used by IITRI. This instrumentation system, or similar systems, was used in the following test programs; lead azide. lead styphnate, tetracene, nitroglycerine, nitroguanidine, guanidine nitrate, M1, M6, M10, M30A1, N5, BS-NACO propellants, and pyrotechnic primer mix, illuminants, and igniter mixtures.

Dugway Proving Ground System

Dugway Proving Ground utilized a different type of instrumentation system for the Benite propellant tests. Their instrumentation system consisted of piezoelectric transducers with source followers, RG-58 coaxial cabling, a signal conditioner/amplifier, transient recorders, and a pulse-coded modulation unit in parallel with the transient recorders.

The piezoelectric transducers, Susquehanna models ST-2 and ST-4 are synthetic and natural crystal-type transducers. The blastwave flexes the crystal producing a signal proportional to the blastwave. Amplification of the signal is accomplished by a Field Effect Transistor (FET) source follower connected directly to the transducer at the source. The signal is transmitted using coaxial cabling to a PCB Model 483A signal conditioner. The signal is then outputed to Biomation Model 610B transient recorders. The transient recorderes were used only on the three closest tranducers in each 90-degree array; whereas, the pulse coded modulation unit was in parallel with, and used for, all twelve channels. Figure 37 shows a block diagram of the instrumentation system. Data reduction was not aluded to in the final report; therefore, description of the data reduction system is not included.

Picatinny Arsenal System

Tancreto[3] used yet a different instrumentation system for the Composition B and the RDX Slurry tests. This system employed piezoresistive transducers, cabling, signal conditioners, amplifiers and magnetic tape recorders.

Data were recorded using two magnetic tape recorders-an Ampex model CP-100 and an Ampex model AR-200. The Ampex model CP-100 was the primary recorder and the Ampex model AR-200 was used as the backup. The recording levels for the model AR-200 were adjusted to the signal levels one-fifth of the anticipated fill-scale values. The recording format was the same for both recorders: 13 FM recording tracks and a single direct recording channel for the time base signal. Data recorded on the model AR-200 were reproduced on the model CP-100, when required. The blast pressure data were recorded an a speed of 1524 mm/s (60 ips) and reproduced at a tape speed of 47.6 mm/s (1-7/8 ips).

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Tancreto[3] used yet a different instrumentation system for the Composition B and the RDX Slurry tests. This system employed piezoresistive transducers, cabling, signal conditioners, amplifiers and magnetic tape recorders.

The piezoresistive pressure transducers were manufactured by Tyco Instrument Division of Bytrex, Incorporated. This type of gage was suppiled with an intergal heat and debris shield with eight equally spaced holes 1.016 mm (0.040 inch) in diameter leading to the gage diaphragm. The filter provides a cylindrical 0.254 mm (0.010 inch) air space above the diaphragm. The diameter of the space varies with the pressure range of the gage. Gages designed to measure peak pressure of 103, 172, 689, 1379, 3447, and 6895 kPa (15, 25, 100, 200, 5000, and 10000 psi) were placed along the gage line in accordance with predicted pressures at the gage location.

In the beginning of the test program a nominal 20 kHz recording system was used. This system consists of Endeveco model 4401 and 4470 signal conmditioners, Dana model 385V2 and 4472-6 amplifiers, and a Sangamo Saber 4 tape recorder with a 1524 mm/s (60 ips) recording speed. A nominal 40 kHz recording system was substituted for later tests. This system used Minneapolis-Honeywell model 104 amplifiers and increased the tape recording speed to 3048 mm/s (120 ips). The 20 kHz system was used for the hemispherical Composition B, RDX slurry tests and a portion of the the elevated Compositon B tests. The nominal 40 kHz system was used for the remainder of the tests. The output FM signal was digitized at 160 and 320 samples/src, representing 6.25 and 3.125 s per data point for the 20 and 40 kHz recording systems respectively.

AMCCOM Resident Operations Office System

The instrumentation system used by AMCCOM Resident Operations Office personnel at NASA/National Space Technology Laboratories, NSTL, Mississippi consisted of piezoelectric pressure transducers with built-in source followers and underground coaxial cabling connecting them to a voltage amplifier and to either a transient recorder or a digital oscilloscope. Playback was outputed to a microprocesser graphics display system. A visicorder employing fiber optics was used for the real-time quick-look data source. This instrumentation system is shown in Figures 38, 39, and 40.

PCB Piezotronics models H101A02, H101A4, H101A12, A101A and 106B representing pressure ranges of 34,738, 6895, 1724, 689, and 69 kPa (5000, 1000, 250, 100, and 10 psi), respectively, were used to capture the blast wave. The PCB transducers are quartz crystal type transduers with their source followers inseparable joined as a sealed assembly. The outputs coupled to a Dial-Cal voltage amplifier PCB model 494A06 either amplify or attenuate the output signal from the transducer matching the input range of the recording instrument. Figure 41 shows the a block diagram of the typical blast measurement system employed by NSTL personnel.

Two different types of recording systems were used for the various test programs. Initially, Biomation model 8100 transient recorders and a Honeywell model 96 tape recorder were used to capture the data. The model 8100 transient recorders captured the first two gages of each leg of the 90-degree array and the Honeywell model 96 recorder was in parallel with the Biomation recorders. The Biomation transient recorder sample rate was 1 s for a total of sample time of 2.05 ms. The magnetic tape recorder speed was 1524 mm/s (60 ips). All channels from the magnetic tape recorder were played back at 47.63 mm/s (1-7/8 ips) through the Biomation recorders, digitized and coupled to a Tektronix 4052 graphics display microprocesser, and plotted using developed basic computer language programs. Peak pressure and impulse values were then determined. The output from the magnetic tape recorder was also coupled to a Honeywell model 1858 visicorder to determine positive phase duration and time of arrival.

The latest system used to record the blast data consisted of six Nicolet model 206 Explorer II Digital Oscilloscopes. These digital oscilloscopes have a 32-K mainframe memory with an additional eight-track floppy disc storage capability of 32 K. These scopes are dual-channel simultaneous record-type scopes. Each channel represents 2048 12-bit words or a single channel of data at 4096 12-bit words. Each scope was set up to measure corresponding peak pressure and impulse values from each pressure transducer of 90-degree array. Calibration and real-time data were stored on a seperate track of the floppy disc for a permanent record. The Nicolet output is directly coupled to the Tektronix 4052 through a GPIB bus interface. The output from the Nicolet was compataible with the Tektronix 4052 graphics display system without any modification to the basic language computer program.

The above descriptions represent only a cursory synopsis of the various instrumentation systems employed to obtain the test data. Detailed information or descriptions may be found in the individual cited reports of each material considered for test. Data analysis from each of these systems was performeded in an exact same manner. Data analysis is described in a seperate chapter.

All of the test agencies used some form of high-speed camera coverage to obtain fireball diameter and fireball duration. Generally, framing cameras from 500 , 1,000 to 10,000 fps were used. These data are not reported as a part of the compendium but can be found in the individual test reports cited.

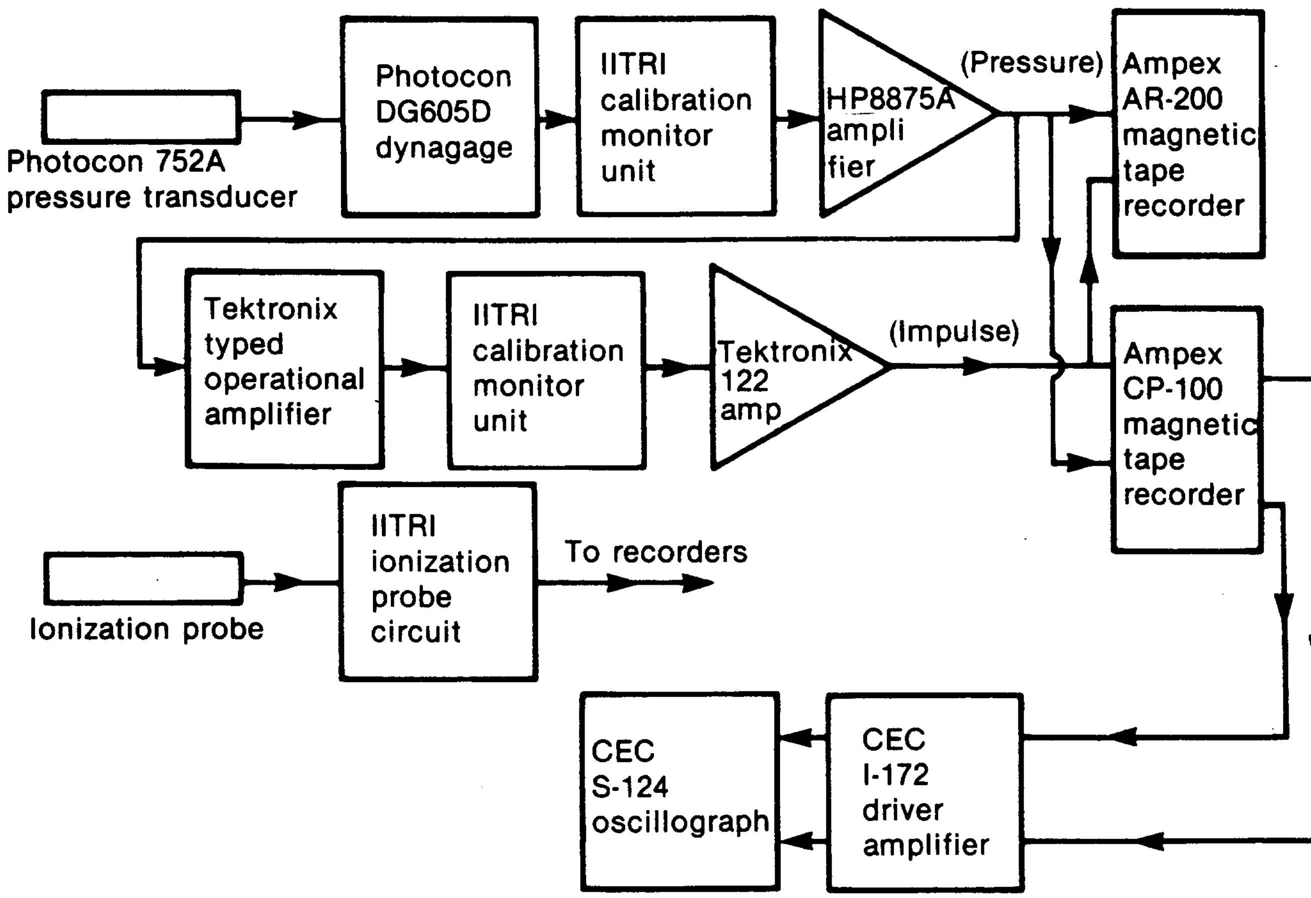


Figure 36. Block Diagram of Record/Reproduce Instrumentation Sysem Used by IITRI.

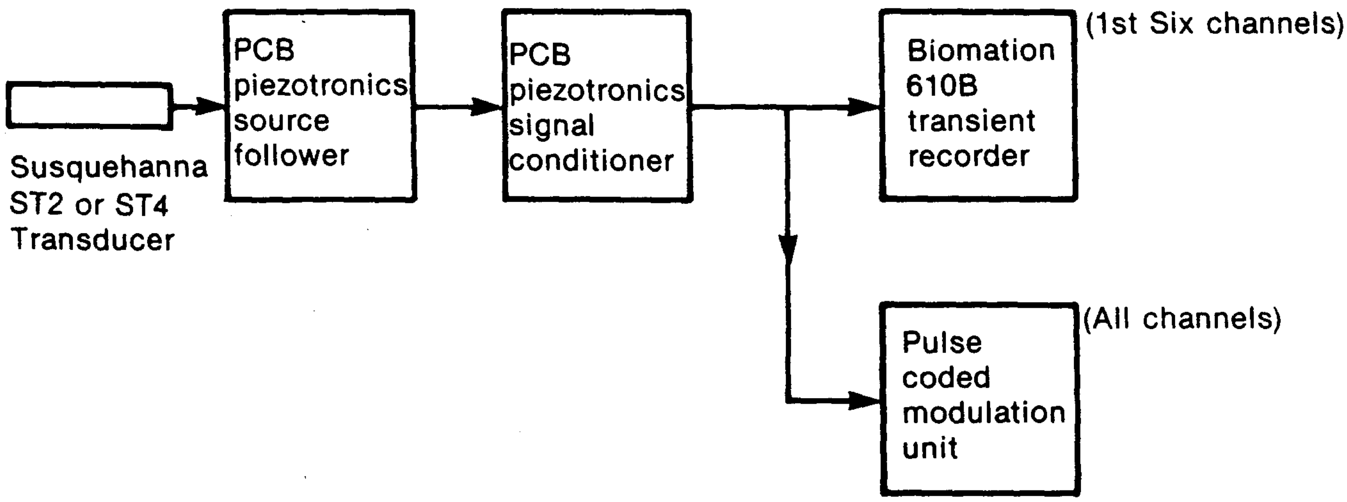


Figure 37. Dugway Proving Ground Blast Instrumentation Blast Recording System Block Diagram.

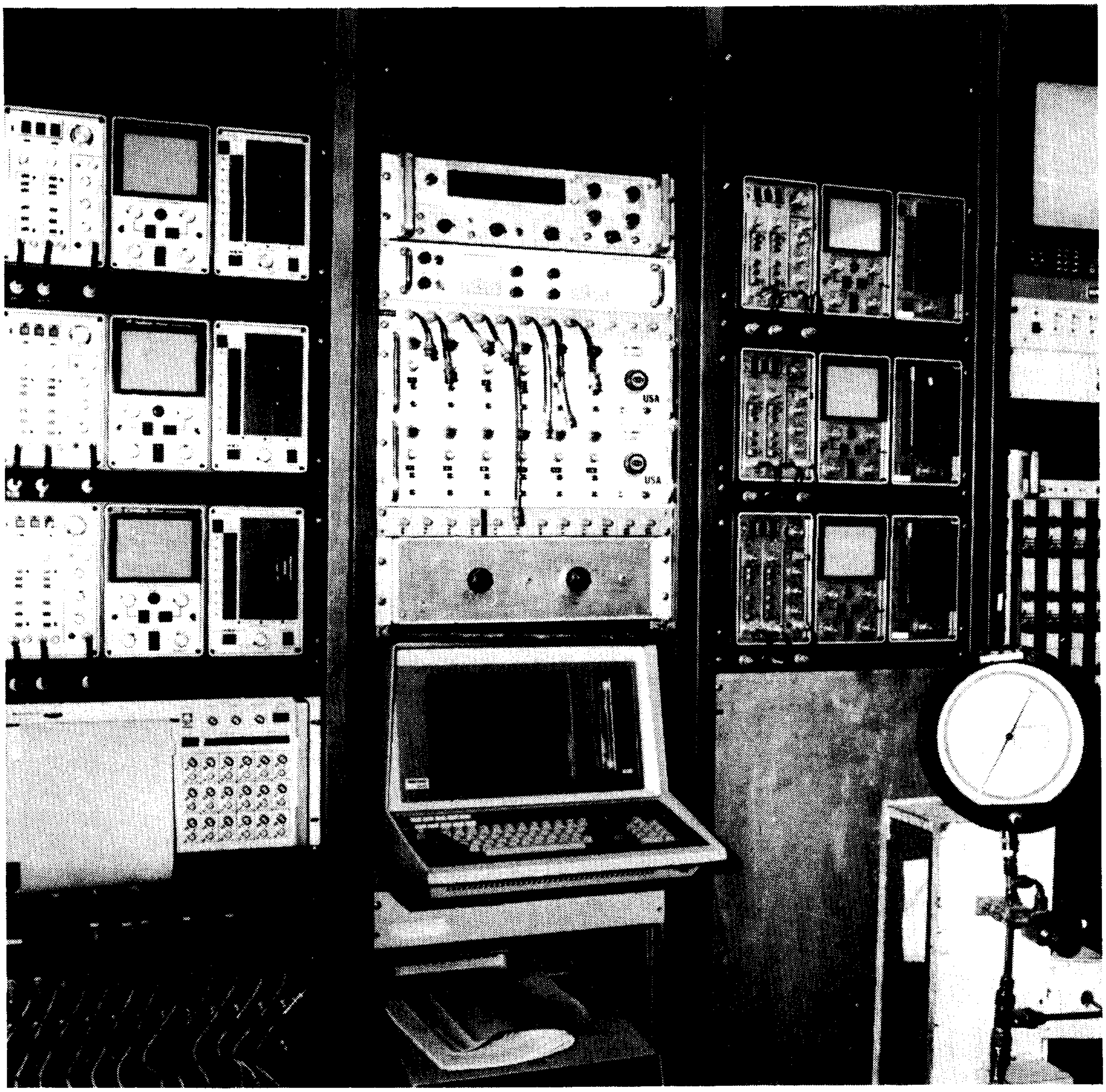


Figure 38. Interior View of Blast Measurement Recording System and Microprocessor.

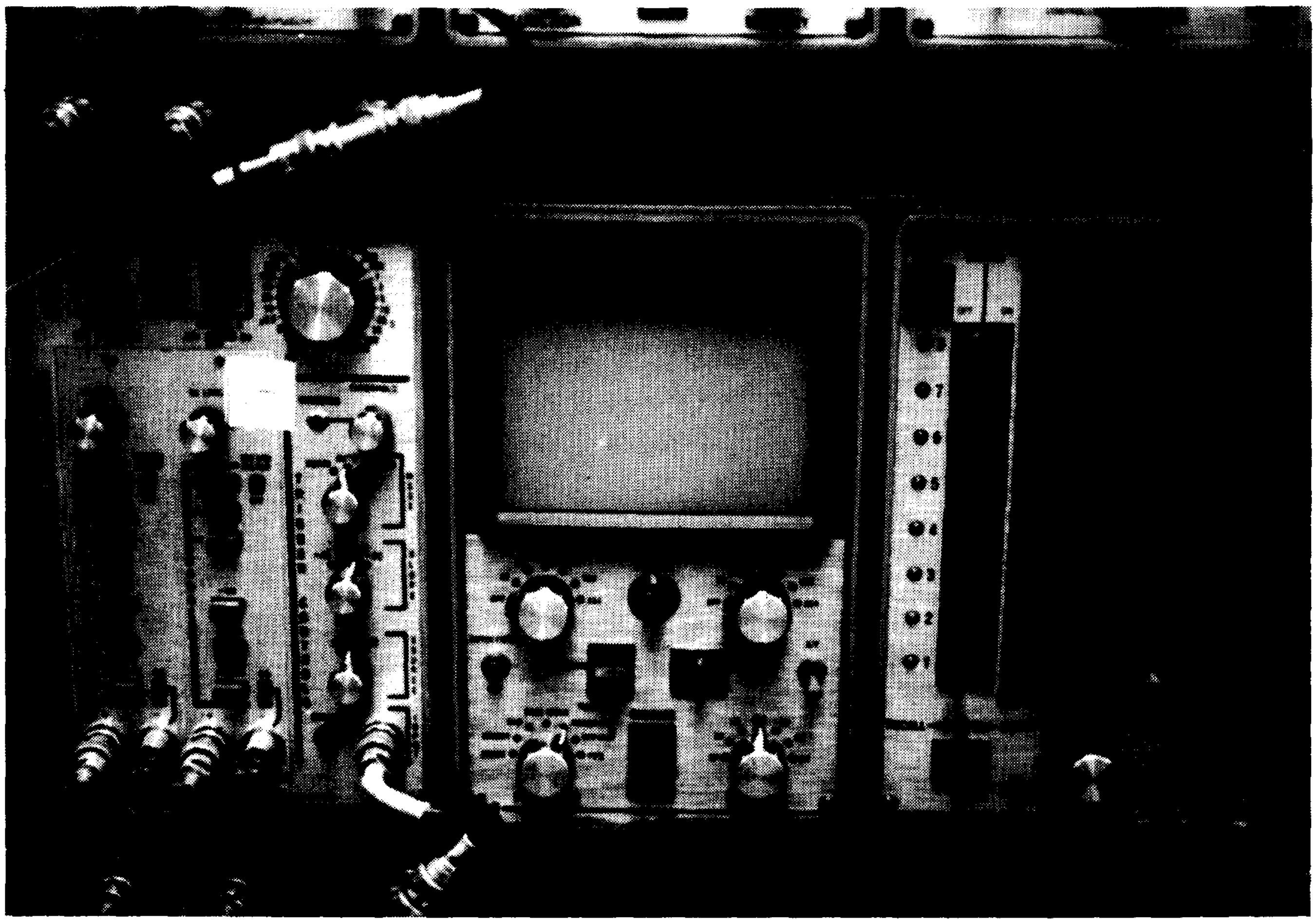


Figure 39. Typical Nicolet Model 2090 Explorer II Digital Ocsilloscope.

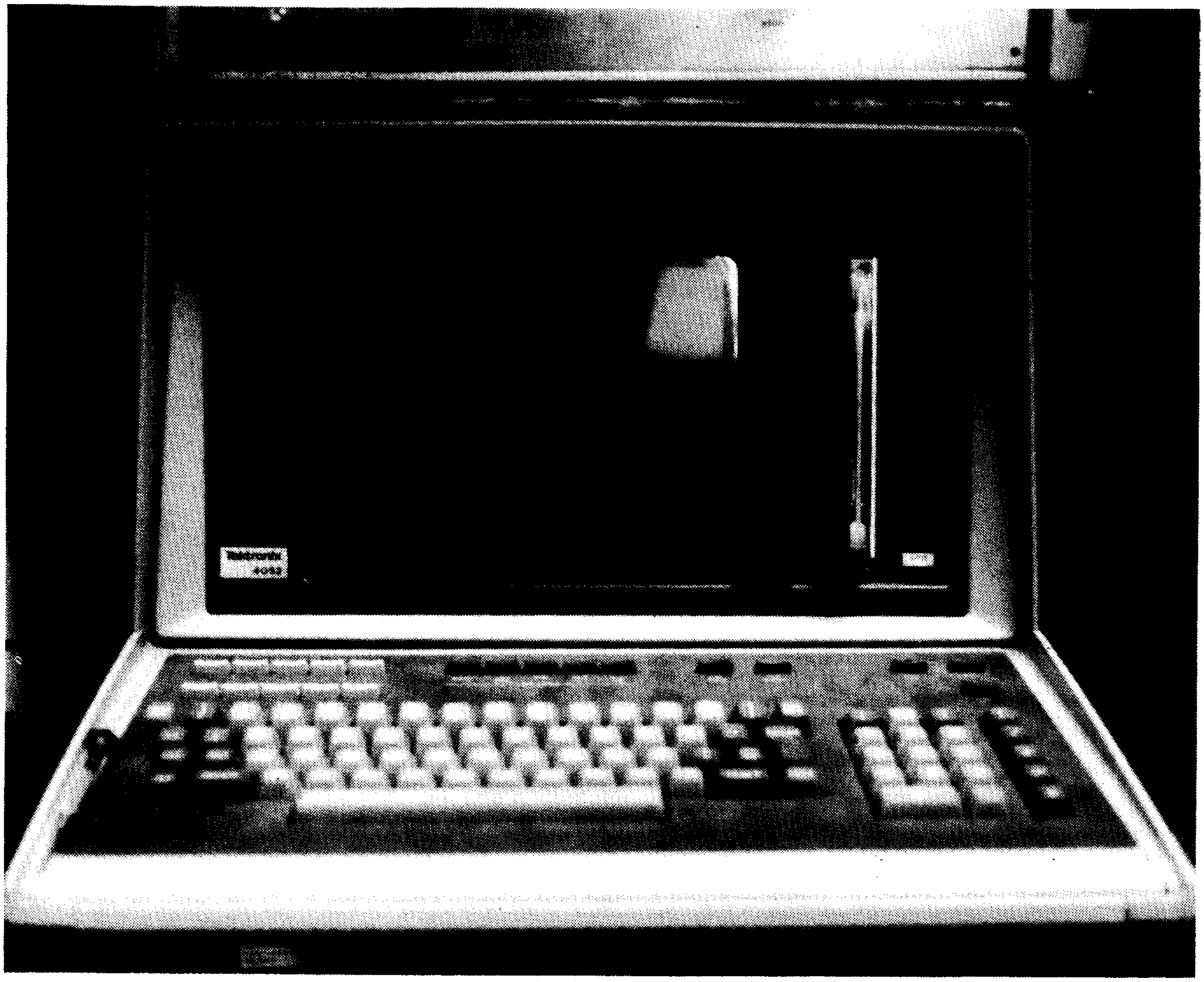


Figure 40. Tektronix Model 4052 Graphic Display Unit.

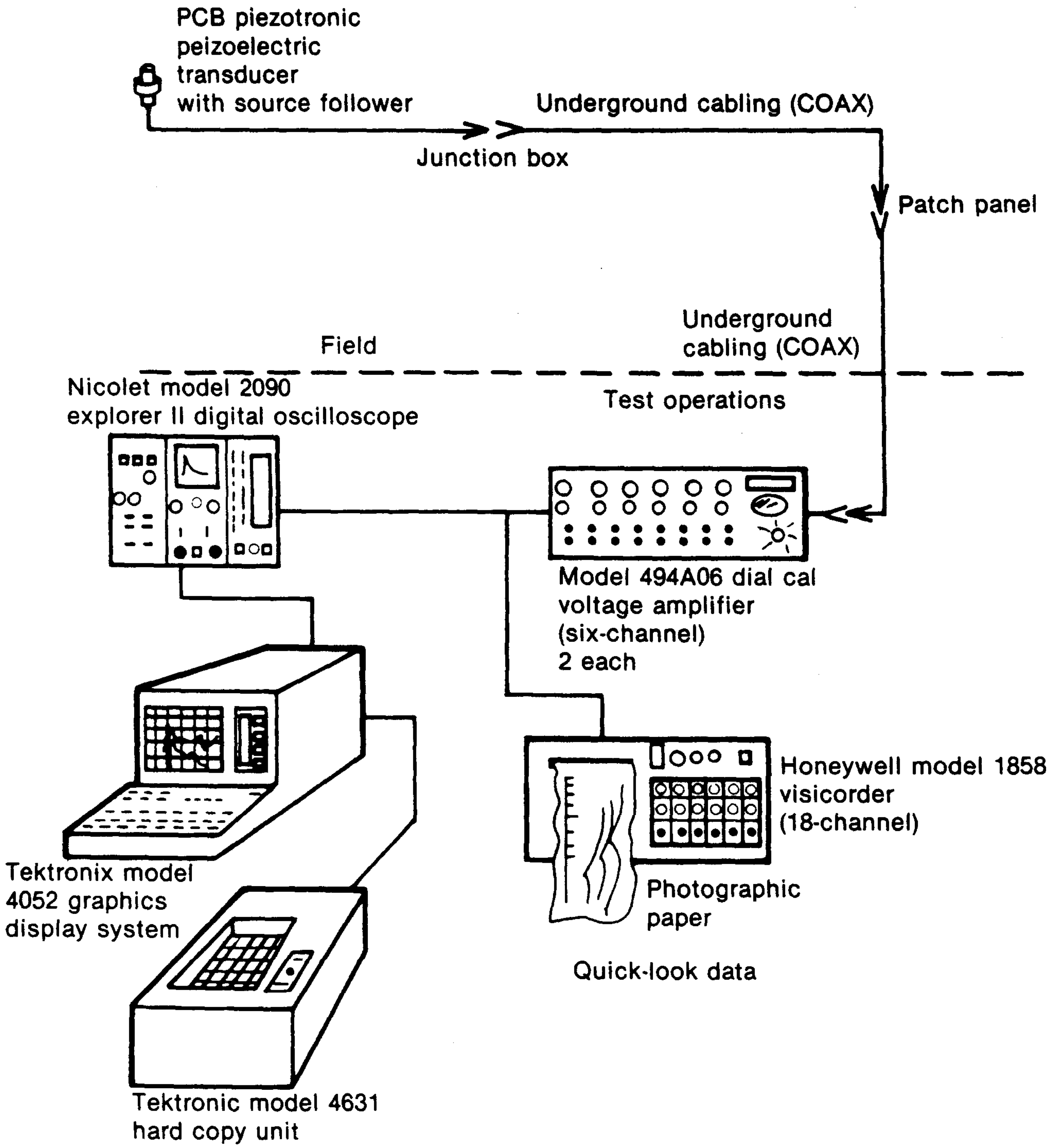


Figure 41. Typical Blast Measurement System.

DATA ANALYSIS

DATA ACQUISITION

The pressure time profile was captured in either analog or digital form utilizing either magnetic tape recorders, digital transient recorders, or digital oscilloscopes. The stored data were then digitized in one form or another for computer analysis. Since the digitizing techniques used by other experimenters were not reported in sufficient detail to be included in this report, only the digitizing techniques and data reduction techniques used by the author will be discussed. Figure 42 is a simplified block diagram of the data acquisition and reduction system. The data acquisition program is given in Appendix A.

The pressure time profiles were recorded in digital form utilizing a Nicolet Model 206 Explorer II digital oscilloscope. Simultaneous signals ("A" and "B" channels) were recorded in the 32-K mainframe memory as well as being stored on a floppy disc as a permanent record. The data were outputed through an input/output circuit via a "handshake" routine to the input of the Tektronix Model 4052 graphics display system. A data acquisition program written in "basic" language plotted a graph of blast pressure, calculated the total impulses, and annotated the plot. The pressure value was plotted in words versus time, and the impulse was given as words times time. The Y-axis units represented 20 words per unit versus 100 sample intervals for the X-axis. Zero or baseline was calculated from the average of the first 20 words until peak pressure rose. The impulse was then automatic until the pressure value decayed to the calculated zero values; then the impulse value appeared and was noted by an asterisk. A hard copy of the pressure and impulse was made using the hard copy unit. A typical plot is shown in Figure 43.

Once the plot had been obtained for all measurements, each data point was compared with data from the corresponding gage at the same scaled distance from the other leg of the 90-degree array. Time of arrival (obtained from the visicorder), positive duration, peak pressure, and impulse were checked against predicted values to determine if there were instrumentation malfunctions, improper calibration, poor transducer placement, and/or impingement of fragments on the transducer element. Data that could be attributed to instrumentation malfunctions or other anomalies such as poor explosive behavior were excluded from further calculations. The mean and standard deviations for peak pressure and impulse were then computed. All data which fell outside one standard deviation were excluded from the TNT calculation. The remaining data were imputed into the computer for data reduction and analysis. The computerized data reduction is given in Appendix B.

All data from the various experimenters were analyzed and reduced using the same computer program. Where other experimenters may not have held scaled distance constant, the curves and tables generated by the computer program ranged from scaled distances of 1.19 m/kg to 15.87 $m/kg^{1/3}$ (3 $ft/lb^{1/3}$ to 40 $ft/lb^{1/3}$); thus, all data were treated in a consistent format.

DATA REDUCTION

Pressure Equivalency

TNT equivalency (E) of a weight (W) of an explosive is defined as:

$$E = W_{TNT}/W_{x} \tag{1}$$

where W_{TNT} is the weight of the quantity of TNT that produces the same effect (explosive yield) at an equal radial distance. Thus, W_{TNT} versus scaled distance can be shown as

$$Z_{TNT} = R/W_{TNT}^{1/3} \tag{2}$$

However, in these experiments a booster charge was used to initiate the test material. The weight of the booster charge varied from 1 to 10% for the various experiments. In order to calculate the TNT equivalency of the test sample only, it was necessary to factor out the contribution of the booster. In the majority of the experiments, Composition C4 was used as the booster. It has been determined by empirical data that the TNT equivalency of the booster is 1.25.

Assuming that TNT equivalency of Composition C4 is 1.25, substituting this value into the denominator of Equation (1) will yield:

$$W_{TNT} = W_{s} + 1.25\ W_{B}/E, \tag{3}$$

where W_{s} is the weight of the samples and W_{B} is the booster weight. Subsituting Equation (3) into Equation (1) yields:

$$E = W_{TNT}/(W_{s} + 1.25\ W_{B}/E), \tag{4}$$

which can be solved for E:

$$E = (W_{TNT} - 1.25\ W_{B})/W_{s} \tag{5}$$

Using Equation (2) and substituting, W_{TNT} is eliminated by:

$$E + \left[(R/Z_{TNT})^{3} - 1.25\ W_{B}\right]/W_{s} \tag{6}$$

Pressure equivalency can now be calculated with the booster weight factored out. However, the booster weight must still be factored out to determine impulse equivalency.

Impulse Equivalency

Impulse equivalency was calculated by combining Equations (1) and (3) to eliminate the explicit E dependence, yielding:

$$W_{TOT} = W_s + 1.25\ W_B/(W_{TNT}/W_{TOT}) \qquad (7)$$

This equation was of the form

$$x = f(x) \qquad (8)$$

where $x = W_{TOT}$. By assuming an initial value x_o and using an iterative procedure

$$X_{i+i} = f(x_i) \qquad (9)$$

convergence was guaranteed when conditions

$$|f'\ (x)| \leq q \leq 1 \text{ for } a \leq x \leq b \qquad (10a)$$

$$a \leq x_o \pm |f(x_o) - x_o|/(1 - q) \leq b \qquad (10b)$$

were satisfied, where

$$a \leq x \leq b \qquad (10c)$$

The application of these conditions to Equation (7) showed that the above iterative process always converged to the correct solution when the "first assumption" W_o satisfied $W_o \leq W_{TOT}$. The computer program used $W_o = W_s$, which was large enough, unless E was so small that the second term of Equation (7) dominated the first.

Substitution:

$$W_{TNT}/W_{TOT} = \left(Z_{TOT}/Z_{TNT}\right)^3 \qquad (11)$$

could be made, where Z_{TOT} was given by a relation that was similar to Equation (2) but involved W_{TOT}. The iterative procedure for impulse in the computer program was

Step 1. $i = o$. Set $W_{TOT_{(i)}} = W_{TOT_{(o)}} = W_w$. Give $E_i = E_o$ some value.

Step 2. Calculate $TOT_{(i)} = R/W_{TOT}^{1/3}$.

Step 3. Obtain Z_{TNT} from measured impulse via a curve fit (using E_i).

Step 4. Calculate $E_{i+i} = \left[Z_{TOT_{(i)}}/Z_{TNT}\right]^3$.

Step 5. Calculate $W_{TOT_{(i+i)}} = W_s + 125\ W_B/E_{(i+i)}$.

Step 6. Test convergency (program checks $|E_{(i+i)} - E_i|$).

If no convergence, then increment i and go to step 2, else exit loop.

The desired quantity, E, is calculated as a byproduct of this calculation.

Pressure equivalency was calculated directly from Equation (6). Impulse equivalency was obtained by the above iterative process. At each scaled distance, sample means and standard deviations for pressure, scaled impulse, pressure equivalency, and impulse equivalency were calculated using standard formulas. Figure 44 shows a typical computer output.

Once the mean value and standard deviation values for peak pressure, scaled positive impulse, pressure equivalency, and impulse equivalency were determined, the computer program then performed a curve fitting routine.

Curve Fitting

Polynomial curve fits were made to log y versus (scaled distance), where y represented the mean value of pressure, scaled impulse, pressure equivalency, and impulse equivalency, respectively. For each, fits were made for degree 1 through degree N - 2 (but limited to 10 coefficients), where N was the number of data points (i.e., the number of scaled distances), and a statistical test was used to select the appropriate fit.

N observations were made of some measure y, and were assumed to have the form

$$y(x) = \sum_{k=1}^{n} a_k f_k(x),\ n < N \tag{12}$$

where

a_k = a constant

$f_k(x)$ = any suitable function.

When each $f_k(x)$ was a power of x, a polynomial expansion of y was the result. Matrix notation afforded a simplification of Equation (12). Let a be the vector whose components are a_k and let $\underline{f}$ be the vector whose components are $f_k(x)$. Then, substituting Equation (12), this could be written as

$$y(x) = \underline{f}' \, \underline{a} \tag{13}$$

where $\underline{f}'$ was the transpose of $\underline{f}$.

There was one such equation for each observation. The index i, labeling observations (i = 1, 2, ..., N), was regarded as a subscript of x. Calculations were made simultaneously with the entire collection of observations. This was accomplished by constructing the vector $\underline{Y}$ whose components were the observations $y(x_i)$ and the matrix F whose rows were $\underline{F}'(x_i)$, and were written:

$$\hat{\underline{Y}} = F\underline{a} \tag{14}$$

Let "^" over a quantity denote an estimate of that quantity. Next, the "best" estimate, $\hat{\underline{a}}$, of the vector was required. This was written as

$$\hat{\underline{Y}} - F\hat{a} \tag{15}$$

The generalized-least-squares interpretation of the "best" estimate $\hat{\underline{a}}$ was that which minimized:

$$Q = (\underline{Y} - \hat{\underline{Y}})'W(\underline{Y} - \hat{\underline{Y}}) \tag{16}$$

where W was a matrix whose diagonal elements were the weights of each observation and whose off-diagonal elements were zero.

This result of setting:

$$dQ/d\hat{\underline{a}} = 0 \tag{17}$$

where the vector derivative implied the scalar product by a vector operator whose components were $a/a_{\hat{a}_k}$, is:

$$\underline{a} = [F'WF]^{-1} F'W\underline{Y}. \tag{18}$$

This was the result of solving the "normal equation"

$$[F'WF] \hat{\underline{a}} = F'W\underline{Y} \tag{19}$$

which resulted from Equation (17). The sign of the second derivative showed that $\hat{\underline{a}}$ given by Equation (18) minimized Q. The components of the parameter vector $\underline{a}$, for the case of polynomial fitting, were simply the polynomial coefficients.

Some observations were more uncertain or unreliable than others. These observations should be given less weight in this fitting process than those more certain or reliable. The appropriate weight of each observation was the reciprocal of the square of its measurement uncertainty. The standard deviation was an estimate of that uncertainty. In general, this inverse of the covariance matrix was the appropriate weighting matrix.

The standard deviations obtained by the program referred to the physical quantities, while the fits were made to their logarithms. The appropriate transformation to apply to the standard deviations when fitting log Y was

$$\sigma \rightarrow \sigma /(y \text{ in } 10) \tag{20}$$

This was a special case of the following: If a random variable x had an error ε, then the error δ in $Z = f(x)$ was given by:

$$\delta = [df(x)/dx] \cdot \varepsilon. \tag{21}$$

The choice of the degree of fit was made by an analysis of variance. A sequence of tests was performed comparing each degree of fit with one degree lower. Degree 1 was compared with a constant, the mean of the observations. In each case the null hypothesis was that adding an extra term made no significant difference. The statistical tests were made at a 95% confidence level. Figure 45 shows a typical computer printout of a curve fit.

Plotting

Two graphs were produced by the program. Each contains two curves (pressure and scaled positive impulse) obtained from the polynomial fits and the associated data points (mean values). The first graph shows peak pressure and scaled positive impulse versus scaled distance. The second graph is a plot of pressure and impulse equivalency versus scaled distance. Both graphs are log-log plots.

The ordinates on both graphs are the same. The range of scaled distance values is 2 to 40 $ft/lb^{1/3}$ (0.79 to 15.87 $m/kg^{1/3}$). Tic marks are also drawn in both the upper and lower margins to designate 5.4 and 18 $ft/lb^{1/3}$ (2.14 and 7.14 $m/kg^{1/3}$). (The graphs could have easily been in metric but English units were used as a matter of convenience.) The y-axis scales are determined by the true minimum and maximum values of the data plotted. Automatic scaling is accomplished; grid lines are tagged with the desired numerical values; the axes are labeled to identify the physical quantities plotted; and titles are printed. Figure 46 and 47 show typical plots.

The curves are drawn to display the smoothed functions obtained by the polynomial curve fits. The curve plotted are log (y-value) versus log (scaled distance), where the y-value represents pressure, scaled impulse, pressure equivalency, and impulse equivalency. The triangle symbols represent the mean pressure values and the square symbols represent impulse.

Tabulations

The pressure and impulse polynomial curve fits are used to generate tabulation. These values are tabulated for scaled distances over the range of 3 to 40 ft/lb$^{1/3}$ (1.19 to 15.87 m/kg$^{1/3}$) at intervals of 0.2 ft/lb$^{1/3}$ (0.0079 m/kg$^{1/3}$). Scaled distance, pressure, and scaled positive impulse are tabulated in both English and metric units. The tabulation occupies seven pages, each of which has a complete heading. Figure 48 shows a typical computer tabulation.

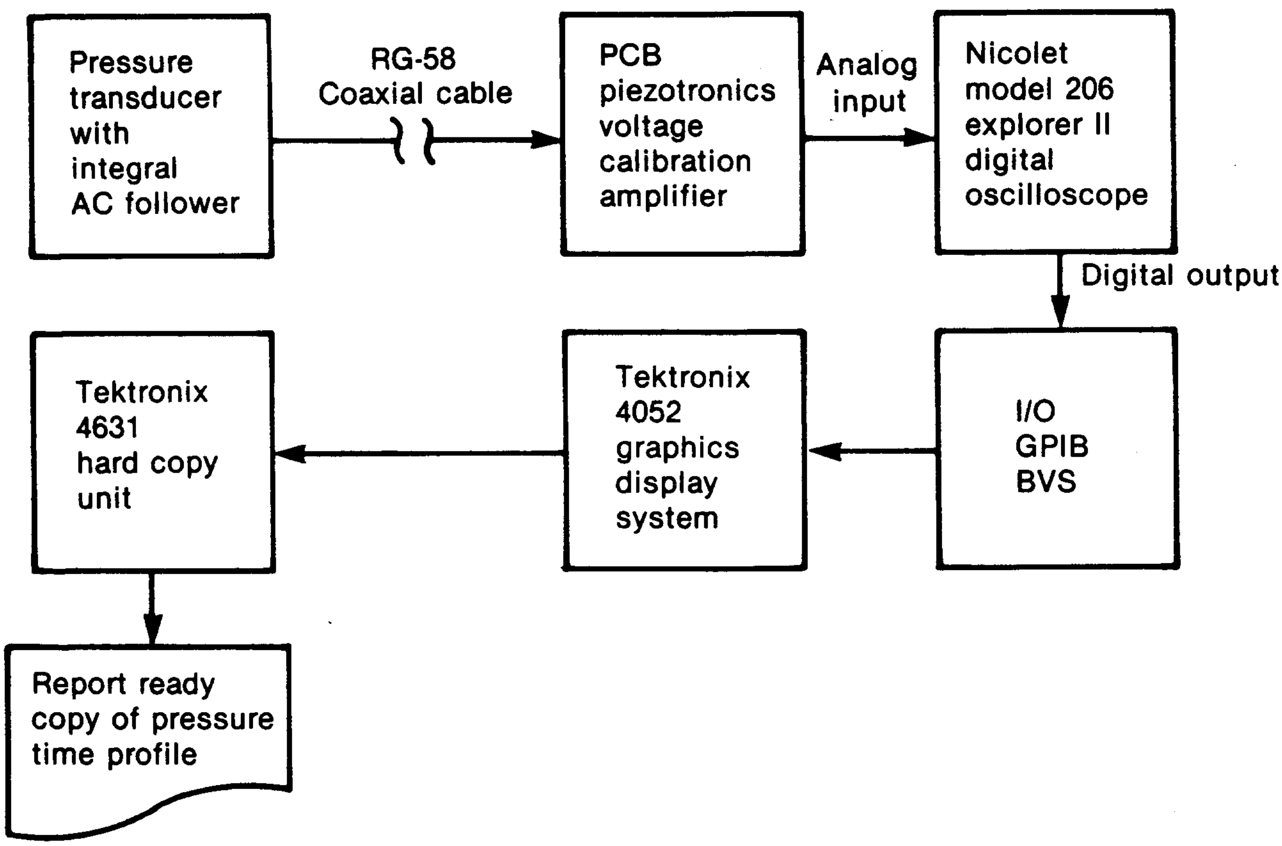
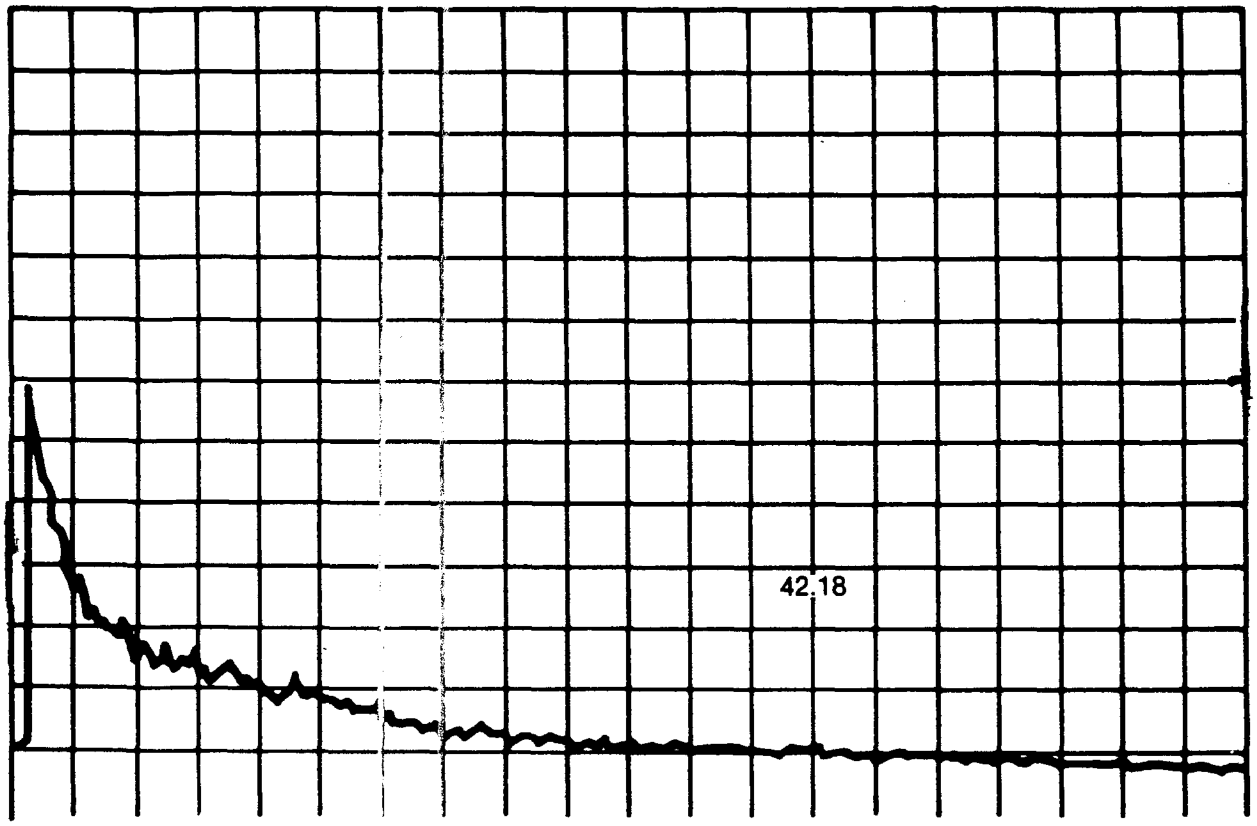


Figure 42. Simplified Block Diagram of Data Acquisition/Reduction System.



Test. . .55LB digl prop   Test number and date. . .03-81-07 01-21-81

Channel. . 1   8100. . .1   Range +/− 2 U.F.S

MSEC per block = 0.200   Words per block = 20

Figure 43. A Typical Plot from the Graphics Display System.

TNT EQUIVALENCY OF COMPOSITION C4 L/D = 0.5:1
CONFIGURATION: STANDARD SHIPPING CONTAINER

	W lb	R ft	Z scaled	P psi	I scaled	E(P) (%)	E(I) (%)
	60.000	11.7400	2.999	370.830	21.119	406	117
	60.000	11.7400	2.999	331.110	21.988	348	125
	60.000	11.7400	2.999	334.670	30.599	354	216
	60.000	11.7400	2.999	316.800	37.383	328	300
	60.000	11.7400	2.999	315.000	25.840	326	164
	60.000	11.7400	2.999	333.330	30.586	352	216
	60.000	11.7400	2.999	277.550	36.653	274	291
	60.000	11.7400	2.999	457.140	30.599	539	216
	60.000	11.7400	2.999	393.940	30.599	441	216
	60.000	11.7400	2.999	300.000	39.031	305	323
	60.000	11.7400	2.999	439.390	45.624	511	417
Sum				3869.760	350.019	4184	2601
Mean				351.796	31.820	380	236
Std. Dev.				57.223	7.415	85	90

Figure 44. Typical Computer Output Showing Computations or Pressure and Impulse Equivalency.

```
COMPOSITION C4 L/D=0.5:1                    STANDARD SHIPPING CONTAINERS
    LOG(PRESSURE)                           VS. LOG(SCALED DISTANCE)

                            COEFFICIENTS

3.36521077282   -0.558180136621    -2.9665220545     1.2907129297

COMPOSITION C4 L/D=0.5:1                    STANDARD SHIPPING CONTAINERS
    LOG(SCALED IMPULSE)                     VS. LOG(SCALED DISTANCE)

                            COEFFICIENTS

2.4861836914              -2.2134295101             0.563214744873

COMPOSITION C4 L/D=0.5:1                    STANDARD SHIPPING CONTAINERS
    LOG(PRESSURE EQUIVALENCY)               VS. LOG(SCALED DISTANCE)

                            COEFFICIENTS

2.0475662559    2.80085703941      -4.2479073953     1.59998363385

COMPOSITION C4 L/D=0.5:1                    STANDARD SHIPPING CONTAINERS
    LOG(IMPULSE EQUIVALENCY)                VS. LOG(SCALED DISTANCE)

                            COEFFICIENTS

-3.95680470276   31.1307252685     -53.0818509759    36.5732768825
-8.78809898011
```

Figure 45. Computer Printout of Polynomial Fit of Peak Pressure and Impulse for Plotting

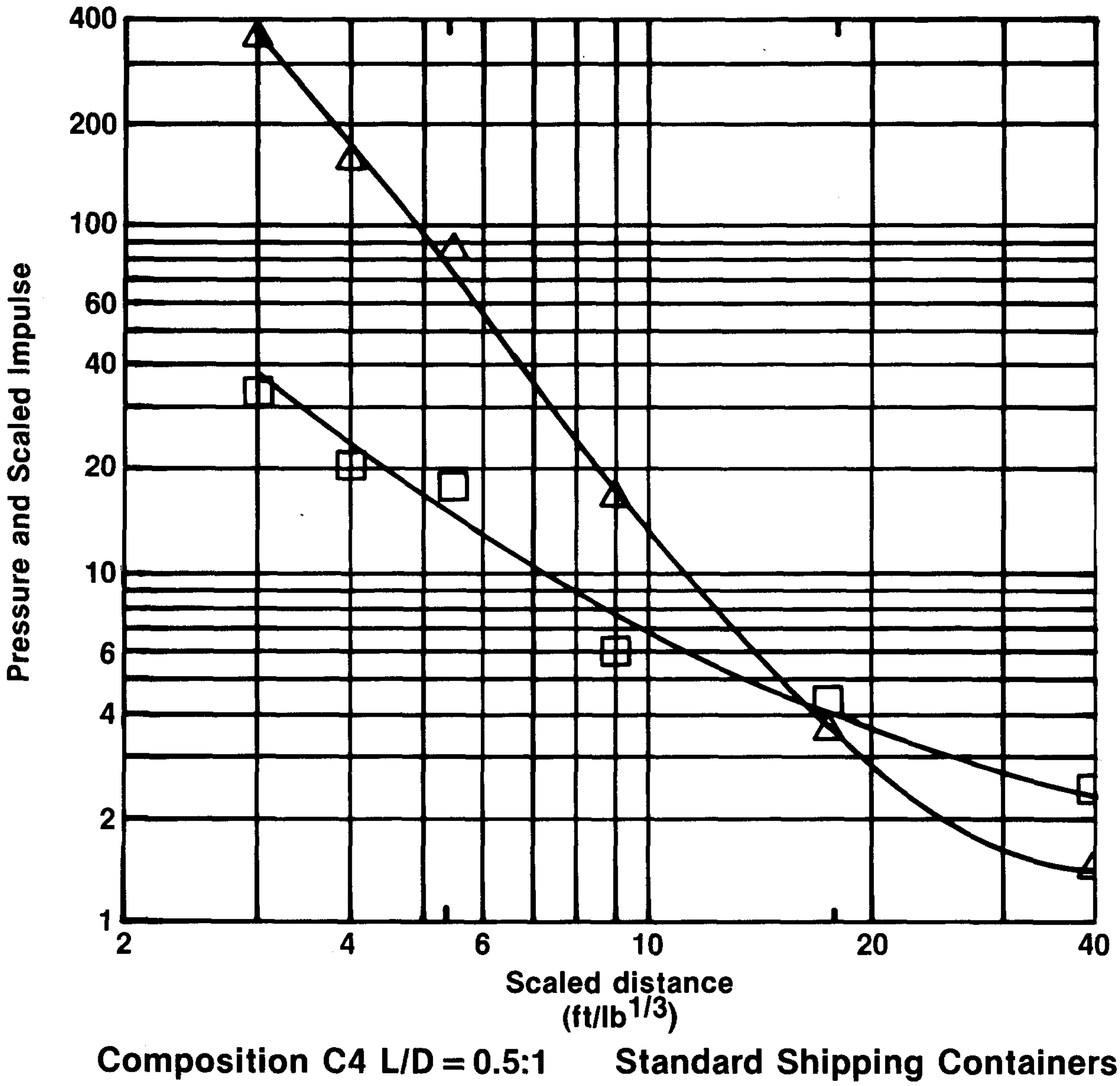


Figure 46. Typical Computer Printout of Pressure and Impulse versus Scaled Distance.

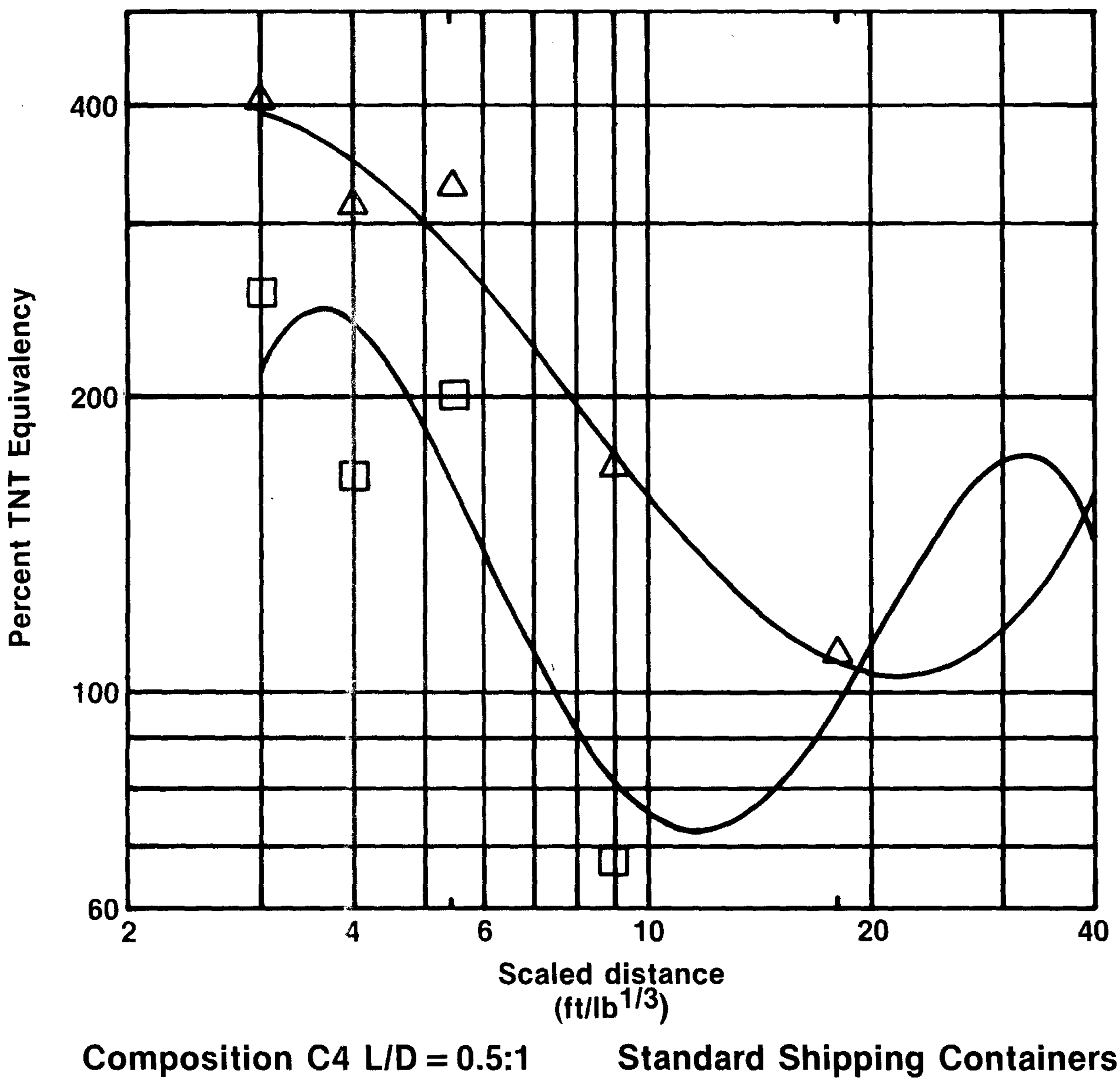


Figure 47. Typical Computer Printout of Pressure and Impulse Versus Scaled Distance.

COMPOSITION C4 L/D=0.5:1 STANDARD SHIPPING CONTAINER

Pressure or Impulse as a Function of Scaled Distance

Scaled Distance ($ft/lb^{1/3}$)	Scaled Distance ($m/kg^{1/3}$)	Pressure (psig)	Pressure (kPa)	Scaled Impulse ($psi \cdot ms/lb^{1/3}$)	Scaled Impulse ($kPa \cdot ms/kg^{1/3}$)
3.000	1.190	366.24	2525.24	36.17	324.57
3.200	1.269	310.91	2143.73	32.49	291.59
3.400	1.349	265.69	1831.90	29.44	264.16
3.600	1.428	228.48	1575.36	26.86	241.06
3.800	1.507	197.67	1362.95	24.67	221.40
4.000	1.587	172.00	1185.96	22.79	204.51
4.200	1.666	150.48	1037.58	21.16	189.86
4.400	1.745	132.33	912.45	19.73	177.06
4.600	1.825	116.94	806.33	18.48	165.80
4.800	1.904	103.82	715.86	17.37	155.84
5.000	1.983	92.58	638.32	16.38	146.96
5.200	2.063	82.89	571.54	15.49	139.02
5.400	2.142	74.51	513.76	14.70	131.88
5.600	2.222	67.23	463.54	13.98	125.43
5.800	2.301	60.87	419.71	13.32	119.57
6.000	2.380	55.30	381.31	12.73	114.24
6.200	2.460	50.40	347.52	12.19	109.37
6.400	2.539	46.08	317.69	11.69	104.90
6.600	2.618	42.24	291.27	11.23	100.80
6.800	2.698	38.84	267.78	10.81	97.01
7.000	2.777	35.80	246.83	10.42	93.51
7.200	2.856	33.08	228.09	10.06	90.26
7.400	2.936	30.64	211.28	9.72	87.24
7.600	3.015	28.45	196.15	9.41	84.43
7.800	3.094	26.47	182.51	9.12	81.81

Figure 48. A Single Page of the Computer Tabulation Based Upon the Best Polynomial Fit.

COMPOSITION A3[4]

OBJECTIVE

The objective of this study was to determine the maximum output from the detonation of Composition A3 high explosives in configurations, which are encountered at sensitive manufacturing process locations, in terms of blast overpressure and positive impulse. The measured values will be compared with known characteristics of hemispherical TNT surface bursts in order to determine the TNT equivalency of Composition A3 relative to TNT.

MATERIAL

Composition A3, Type1, High Explosive (MIL-C-440) is consists of 91% RDX and 9% wax, is used as a molding powder. It has a density ranging from 1.59 to 1.91 g/cm^3. The reported detonation velocity is 8100 m/s at a density of 1.59 g/cm^3 [5].

TEST SETUP

Airblast output in terms of overpressure and positive impulse were evaluated for weights and configurations of Composition A3 that represented sensitive locations and operations of the manufacturing facility. These configurations include a nutsche (handling container) and both scaled and standard shipping containers. Physical characteristics of the test configurations were:

(1) A two-piece telescoping fiberboard box with scaling dimensions of 0.79 was filled with 13.61 kg (30 lb) of Composition A3.

(2) The orginal two-piece telescoping fiberboard shipping container was filled with 27.22 kg (60 lb) of Compostion A3.

(3) A stainless steel nutsche with a linear dimensional scaling factor of 0.52 to full-scale was used. The nutsche container was consturcted from 16-gage stainless steel. The nutsche was filled with 54.43 kg (120 lb) of Composition A3.

The height to length ratios for the three configurations were 0.5:1, 0.5:1, and 0.6:1 for charge weights of 13.61, 27.22, and 54.43 kg (30, 60, and 120 lb), respectively. Five to six tests were conducted at each of the specified charge weights.

The test charges for each configuration were placed at ground zero on a 0.61 x 0.76 x 0.0012 m (2 x 2.5 x 0.04 ft) thick steel witness plate in the center of the test area. The test area was refurbished after each test subsequent to the measurement of the crater diameter and depth.

A conical shaped booster charge of Composition C4 high explosive was placed in the center atop each container. The booster and main charge were detonated with a J2 engineers' special blasting cap inserted at the apex and embedded in the center of the conical-shaped booster charge.

INSTRUMENTATION

Twelve PCB piezoelectric side-on pressure transducers were mounted flush to the surface in a 90-degree array as shown in Figure 1. Distances from the charge to the transducers corresponded to scaled distances from 1.19 to 15.87 $m/kg^{1/3}$ (3 to 40 $ft/lb^{1/3}$). There were two transducers at each corresponding scaled distance of 1.19, 1.59, 2.14, 3.57, 7.14 and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0 and 40.0 $ft/lb^{1/3}$). The corresponding transducers were located on the north/south and east/west gage lines. All transducer measurements were included in the calculations.

RESULTS

Results of each charge weight and configuration are given in the test report. Table 1 and Figure 49 show the combined values of the three different test series. The results were combined because the results of all three test series were similar. The height to length ratios for all three tests were similar and the charge weights scaled. By combining the results of all of the test series, the maximum number of data points are reported. The mean and standard deviation of all of the tests were calculated and all data that fell outside one standard deviation from the mean were excluded from the calculation. The reported values are the average values from all three test series with the booster weight excluded.

DISCUSSION

Charge weights of 13.61, 27.22, and 54.43 kg (30, 60, and 120 lb) were tested. The results of all three tests were similar. Pressure values of the 13.6 kg (30 lb) test series were greater than expected at all scaled distances. The average pressure values were 3064, 1175, 591, 122, 29.4, and 10.2 kPa (444, 170, 85.7, 17.7, 4.26, and 1.40 psi) at scaled distances 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 4.5, 3.8, 2.7, 1.5, 1.2, and 1.6 times greater than equal amounts of TNT at the corresponding scaled distances, respectively. Scaled positive impulse values were greater than expected at all scaled distances with the exception at a scaled distance of 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$). The impulse value was approximately 30% less than equal amounts of TNT at that scaled distance. This was true for all experiments at all charge weights and configurations. Scaled positive impulse values were 406, 239, 165, 72.9, 37.7, and 26.4 $kPa\text{-}ms/kg^{1/3}$ (45.2, 26.6, 18.4, 8.1, 4.2, and 2.9 $psi\text{-}ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.89 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40 $ft/lb^{1/3}$), respectively. The scaled positive impulse values equate 3.2, 2.3, 2.1, 0.7, 1.6, and 1.4 times equal amounts of TNT at the same corresponding scaled distances.

Peak pressure values for the 27.2 kg (60 lb) charge weights were greater than expected at all scaled distances of the experiment. The average pressure values were 3178, 1272, 626, 111, 24, and 10 kPa (461, 184, 90.8, 16.1, 3.49, and 1.45 psi) at scaled distances of 1.19, 1.57, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0 and 40.0 $ft/lb^{1/3}$), respectively. These values equate to 5.5, 2.6, 2.2, 1.5, 1.1, and 1.5 times equal amounts of TNT at the same scaled distances, respectively. These values fell within the mean and standard deviation of the 13.6 and 54.4 kg (30 and 120 lb) tests. The scaled positive impulse values were greater than expected at all scaled distances of the experiment with the exception of the value at 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$). Again, this value was approximately 25% less than equal amounts of TNT at this scaled distance. Average scaled positive impulse values were 315, 220, 148, 61, 49, and 22 kPa-$ms/kg^{1/3}$ (35.1, 24.5, 16.5, 6.84, 5.49, and 2.46 psi-$ms/ft^{1/3}$) at scaled distances of 1.19, 1.57, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0 and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 3.2, 1.7, 1.7, 0.7, 1,7, and 1.4 times equal amounts of TNT at the same scaled distances, respectively.

Peak pressure values for the 54.4 kg (120 lb) charge weights were greater than expected at all scaled distances. The pressure values were 3050, 1166, 585, 119, 28, and 9.58 kPa (442, 169, 84.8, 17.3, 4.1, and 1.39 psi) at scaled distances of 1.19, 1.57, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These values equate to 5.5, 3.8, 2.7, 1.5, 1.2, and 1.4 times equal amounts of TNT at the same scaled distances, resppectively. Scaled positive impulse values were 227, 171, 127, 77, 39, and 18 KPa-$ms/kg^{1/3}$ (25.7, 19.1, 15.3, 8.6, 4.3 and 1.98, psi-$ms/lb^{1/3}$) at scaled distances of 1.19, 1.57, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0 and 40.0 $ft/lb^{1/3}$), respectively. These values equate to 2.4, 2.0, 1.4, 0.7, 1.3, and 1.2 times equal amounts of TNT at the same scaled distances, respectively.

Based upon the experiments of the three different charge weights with approximately the same height to length ratio, the results were combined and these are the values reported in Table 1 and Figure 49. The average pressure values of the combined experiments were 3015, 1272, 495, 112, 27 and 10 kPa (437.3, 184.4, 71.8, 16.3, 3.9, and 1.45 psi) at scaled distances of 1.19, 1.57, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$) respectively. The average scaled positive impulse values were 243, 173, 99, 45, 37, and 16 kPa-$ms/kg^{1/3}$ (35.2, 25.1, 14.4, 6.6, 5.4, and 2.4 psi-$ms/lb^{1/3}$) at the same corresponding scaled distances as the pressure measurements.

The dip in the scaled positive impulse at a scaled distance of 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$) was noted for all experiments. Such a dip was noted when other explosives were tested in similar configurations and similar height to length ratios. The dip could possibly be the effect of the geometry of the test or the experimental method.

CONCLUSIONS

(1) Pressure values for all charge weights were greater than expected at all scaled distances of the experiment.

(2) Impulse values were greater than expected at all scaled distances of the experiment with the exception noted at the scaled distance of 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$).

(3) To within experimental error, charge weights scaled as a function of the cube root.

Table 1. Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse Values for Composition A3 in Orthorhombic Containers, L/D=0.5:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	437.34	3015.45	35.23	316.16	22.000	8.727	2.88	19.86	5.48	49.18
4.000	1.587	184.42	1271.57	25.10	225.22	23.000	9.124	2.72	18.75	5.45	48.94
5.000	1.983	91.37	629.97	16.69	149.76	24.000	9.521	2.58	17.77	5.40	48.49
6.000	2.380	51.85	357.50	11.84	106.25	25.000	9.917	2.45	16.90	5.33	47.82
7.000	2.777	32.70	225.46	9.11	81.72	26.000	10.314	2.34	16.13	5.23	46.92
8.000	3.174	22.37	154.23	7.52	67.45	27.000	10.711	2.24	15.44	5.10	45.80
9.000	3.570	16.30	112.39	6.56	58.89	28.000	11.108	2.15	14.81	4.96	44.49
10.000	3.967	12.48	86.08	5.98	53.67	29.000	11.504	2.07	14.24	4.79	42.98
11.000	4.364	9.95	68.59	5.63	50.53	30.000	11.901	1.99	13.72	4.60	41.32
12.000	4.760	8.18	56.43	5.43	48.71	31.000	12.298	1.92	13.23	4.40	39.51
13.000	5.157	6.91	47.66	5.32	47.76	32.000	12.694	1.85	12.79	4.19	37.58
14.000	5.554	5.96	41.12	5.28	47.40	33.000	13.091	1.79	12.37	3.96	35.57
15.000	5.950	5.24	36.12	5.28	47.42	34.000	13.488	1.74	11.97	3.73	33.49
16.000	6.347	4.67	32.19	5.31	47.67	35.000	13.884	1.68	11.60	3.50	31.38
17.000	6.744	4.21	29.06	5.35	48.05	36.000	14.281	1.63	11.26	3.26	29.26
18.000	7.141	3.85	26.51	5.40	48.45	37.000	14.678	1.58	10.92	3.03	27.15
19.000	7.537	3.54	24.41	5.44	48.82	38.000	15.075	1.54	10.61	2.79	25.08
20.000	7.934	3.28	22.66	5.47	49.09	39.000	15.471	1.49	10.31	2.57	33.06
21.000	8.331	3.07	21.15	5.49	49.22	40.000	15.868	1.45	10.02	2.35	21.10

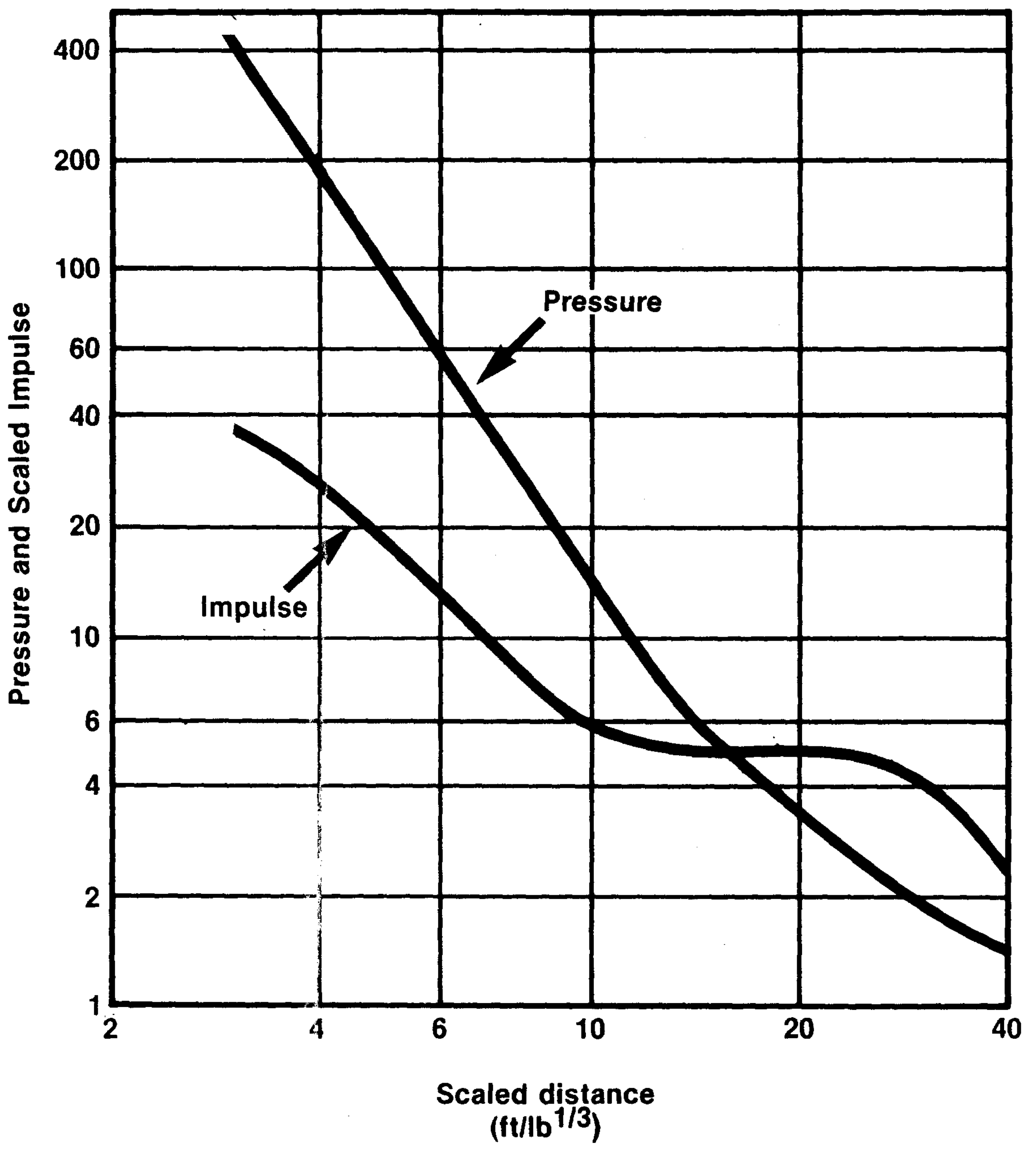


Figure 49. Pressure and Impulse Versus Scaled Distance for Composition A3 in Orthorhombic Containers, L/D=0.5:1.

COMPOSITION A5[4]

OBJECTIVE

The objective of this study was to determine the maximum output from detonation of Composition A5 high explosives in cylindrical and orthorhombic configurations and to measure peak pressure and positive impulse. These values were then compared with known characteristics of hemispherical surface bursts of TNT to determine the equivalency of Composition A5 relative to TNT.

MATERIAL

Composition A5. Type I. High Explosive (MIL-E-14970A-MU) contains 98.5% RDX and 1.5 (+/-) 0.5% stearic acid. It is a granular type explosive used as a filler in pressed munitions. Composition A5 has a bulk density of 0.95 g/cm^3 and a loading density varying between 1.67 and 1.72 g/cm^3.

Composition A5 was received in orthorhombic fiberboard shipping containers having a 27.2 kg (60 lb) net explosive weight.

TEST SETUP

Airblast output was evaluated for weights and configurations of Composition A5 representative of three shipping and in-plant situations. Physical characteristics of the test items are as follows:

(1) A two-piece telescoping fiberboard orthorhombic container simulating a conveyor bucket, scaled shipping container and a full-scale shipping container. Tests were conducted using charge weights of 11.3, 22.7, and 27.2 kg (25, 50, and 60 lb). The height to length ratio for the orthorhombic container was 0.4:1.

(2) A cylindrical fiberboard shipping drum containing 68.0 kg (150 lb) of Composition A5. The height to diameter ratio was 1.6:1.

The test charge for each configuration was placed on a 0.6 x 0.6 x 0.0012 m (2 x 2 x 0.04 ft) thick 1010 carbon steel witness plate in the center of the test area shown in Figures 1 and 2. The test area was refurbished after each subsequent measurement of crater diameter and depth.

A conical-shaped booster charge of Composition C4 high explosives was placed in the center of the top of each container, buried such that the apex was level with top surface of the test material. The booster was initiated with a J2 engineers' special blasting cap embedded in the center of the cone.

INSTRUMENTATION

Twelve PCB piezoelectric side-on pressure transducers were mounted flush to the surface in a 90-degree array as shown in Figure 1. Distances from the charge to the transducers corresponded to scaled distances from 1.19 to 15.87 $m/kg^{1/3}$ (3.0 to 40.0 $ft/lb^{1/3}$). There were two transducers each at each corresponding scaled distance of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$). The corresponding transducers were located at equal distances on the north/south and east/west gage lines. All transducer measurements were included in the calculations.

RESULTS

The results of the orthorhombic configuration tests with charge weights of 11.3, 22.7, and 27.2 kg (25, 50, and 60 lb) with a height to diameter ratio of 0.4:1 were combined. The results are given in Table 2. and Figure 50. A total of 12 tests were conducted in this configuration. All of the reported values were within one standard deviation of the mean.

The results of the cylindrical test configuration with a charge weight of 68.0 kg (150 lb) with an L/D ratio of 1.6:1 are given in Table 3 and Figure 51. All of the reported values for peak pressure and scaled positive impulse are within one standard deviation of the mean. A total of five tests were conducted in this configuration.

DISCUSSION

The peak pressures for the orthorhombic configuration were greater than expected or equal to the expected values. The pressure values were 1652, 1018, 408, 79, 23, and 11 kPa (239.7, 147.7, 59.2, 11.5, 3.4, and 1.6 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $lb/ft^{1/3}$), respectively. These values equate to 2.3, 2.7, 2.0, 1.0, 1.0, and 2.0 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were 363, 265, 177, 86, 39, and 24 $kPa\text{-}ms/kg^{1/3}$ (40.4, 29.5, 19.7, 9.5, 4.4, and 2.7 $psi\text{-}ms/lb^{1/3}$) at scaled distances of 1.19, 1.57, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0 and 40.0 $ft/lb^{1/3}$), respectively. These values equate to 3.4, 3.0, 2.3, 1.4, 1.1, and 1.6 times equal amounts of TNT at the same scaled distances, respectively. Generally, the scaled positive impulse values were greater than expected at all scaled distances.

The peak pressure values for the cylindrical configuration with an L/D ratio of 1.6:1 were greater than expected at all scaled distances of the experiment. Generally, the values were higher at all scaled distances than those obtained in the orthorhombic configuration. The pressure values were 1937, 1355, 562, 104, 28, and 9.7 kPa (280.9, 196.6, 81.5, 15.1, 4.1, and 1.4 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These values equate to 2.7, 4.2, 3.0, 1.5, 1.4, and 1.5 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were greater than or equal to the expected values at all scaled distances. The scaled positive impulse values were 392, 242, 150, 76, 41, and 21 kPa-ms/$kg^{1/3}$ (43.6, 27.0, 16.7, 8.5, 4.6, and 2.3 psi-ms/$lb^{1/3}$) at scaled distances of 1.19, 1.57, 2.14, 3.57, 7.14, and 15.87 m/$kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0 and 40.0 ft/$lb^{1/3}$), respectively. These values equate to 3.4, 5.5, 1.5, 1.3, 1.0, and 1.3 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) The TNT equivalency of Composition A5 (Type I) high explosive for both the orthorhombic and cylindrical configurations vary greatly with scaled distance and are generally greater than 100 percent.

(2) Blast pressure and impulse scales with the cube root of the charge weight for both the orthorhombic and cylindrical configurations.

(3) The explosive yield from the cylindirical configuration is greater between scaled distances of 1.2 and 16 m/$kg^{1/3}$ than those pressrue and impulse values obtained for the orthorhombic configurations.

Table 2. Summary of Results of Hemispherical Surface Bursts Peak Pressure and Scaled Positive Impulse Values for Composition A5 in Orthorhombic Containers L/D=0.4:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse psi · ms / $lb^{1/3}$	Scaled Impulse kPa · ms / $kg^{1/3}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse psi · ms / $lb^{1/3}$	Scaled Impulse kPa · ms / $kg^{1/3}$
3.000	1.190	239.71	1652.79	40.43	362.77	22.000	8.727	2.95	20.37	3.70	33.01
4.000	1.587	147.70	1018.36	29.54	265.10	23.000	9.124	2.88	19.88	3.59	32.20
5.000	1.983	76.37	526.59	21.93	196.82	24.000	9.521	2.82	19.42	3.49	31.11
6.000	2.380	41.85	285.82	16.91	151.79	25.000	9.917	2.75	18.99	3.40	30.47
7.000	2.777	24.71	170.37	13.54	121.55	26.000	10.314	2.69	18.57	3.31	29.74
8.000	3.174	16.16	111.45	11.20	100.55	27.000	10.711	2.63	18.15	3.24	29.07
9.000	3.570	11.46	79.02	9.52	85.48	28.000	11.108	2.57	17.72	3.17	28.47
10.000	3.967	8.69	59.89	8.28	74.32	29.000	11.504	2.51	17.27	3.11	27.92
11.000	4.364	6.95	47.92	7.34	65.84	30.000	11.901	2.44	16.81	3.06	27.42
12.000	4.760	5.81	40.06	6.60	59.25	31.000	12.298	2.37	16.33	3.00	26.96
13.000	5.157	5.03	34.68	6.02	54.02	32.000	12.694	2.30	15.83	2.96	26.53
14.000	5.554	4.48	30.88	5.55	49.80	33.000	13.091	2.22	15.31	2.91	26.13
15.000	5.950	4.08	28.12	5.16	46.34	34.000	13.488	2.14	14.78	2.87	25.76
16.000	6.347	3.78	26.07	4.84	43.46	35.000	13.884	2.06	14.22	2.83	25.42
17.000	6.744	3.56	24.51	4.57	41.05	36.000	14.281	1.98	13.65	2.80	25.09
18.000	7.141	3.38	23.31	4.35	38.99	37.000	14.678	1.89	13.07	2.76	24.79
19.000	7.537	3.24	22.35	4.15	37.23	38.000	15.075	1.81	12.47	2.73	24.50
20.000	7.934	3.13	21.57	3.98	35.71	39.000	15.471	1.72	11.87	2.70	24.22
21.000	8.331	3.03	20.92	3.83	34.39	40.000	15.868	1.64	11.27	2.67	23.96

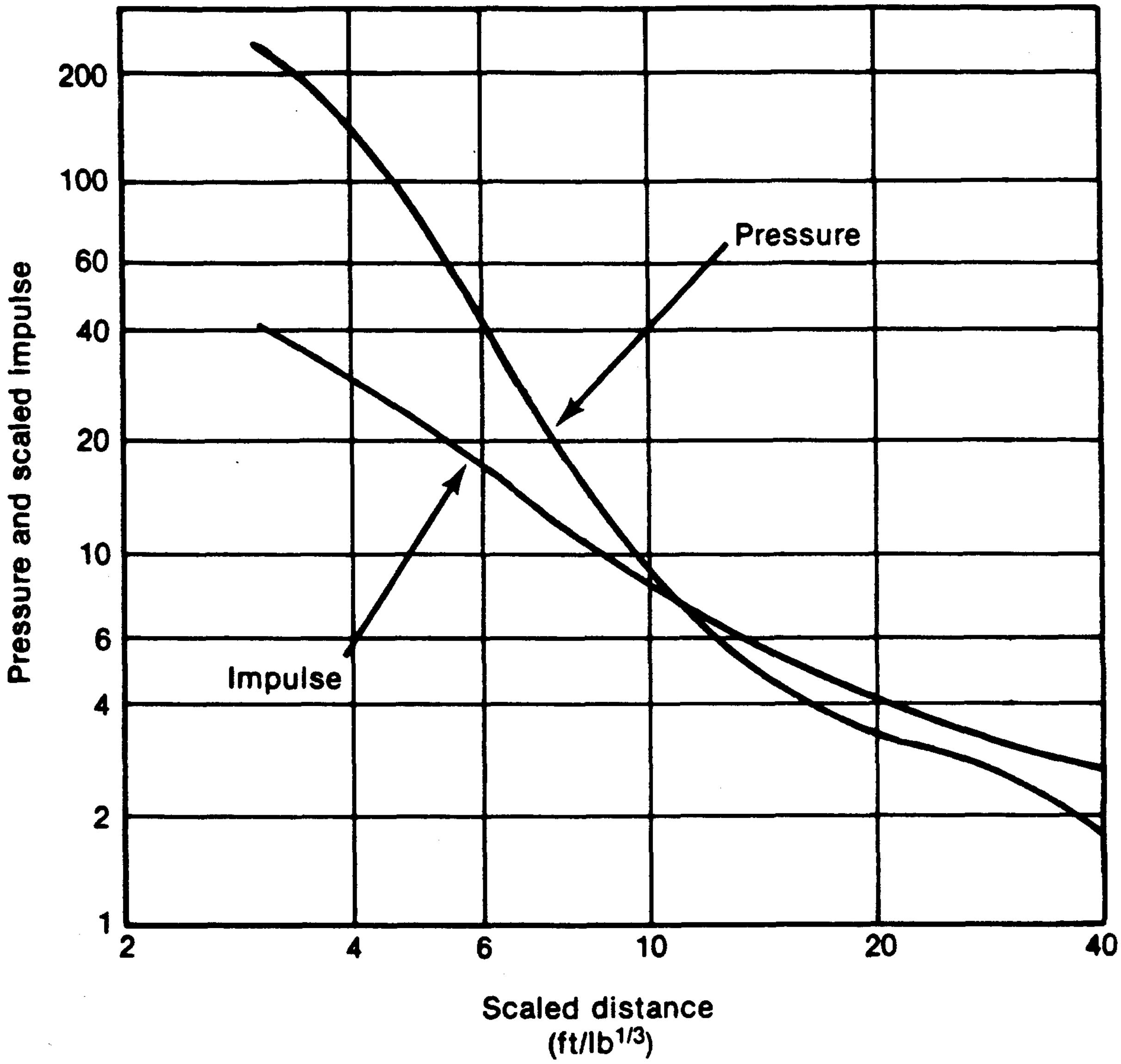


Figure 50. Pressure and Impulse Versus Scaled Distance for Composition A5 in Orthorhombic Containers L/D=0.4:1.

Table 3. Summary of Results of Hemispherical Surface Bursts, Pressure and Scaled Positive Impulse Values for Composition A5 in Cylindrical Containers, L/D=1.6:1

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	280.97	1937.97	43.65	391.75	22.000	8.727	3.42	23.56	3.93	35.31
4.000	1.587	196.59	1355.52	27.00	242.25	23.000	9.124	3.30	22.73	3.81	34.17
5.000	1.983	104.91	723.34	18.83	168.99	24.000	9.521	3.18	21.95	3.69	33.10
6.000	2.380	56.91	392.39	14.31	128.39	25.000	9.917	3.08	21.20	3.58	32.09
7.000	2.777	33.54	231.27	11.55	103.61	26.000	10.314	2.97	20.46	3.47	31.12
8.000	3.174	21.63	149.14	9.73	87.34	27.000	10.711	2.86	19.73	3.37	30.20
9.000	3.570	15.12	104.25	8.47	76.02	28.000	11.108	2.75	18.98	3.27	29.31
10.000	3.967	11.31	77.98	7.55	67.77	29.000	11.504	2.64	18.23	3.17	28.45
11.000	4.364	8.94	61.65	6.86	61.54	30.000	11.901	2.53	17.47	3.08	27.61
12.000	4.760	7.39	50.97	6.32	56.68	31.000	12.298	2.42	16.70	2.99	26.80
13.000	5.157	6.34	43.69	5.88	52.78	32.000	12.694	2.31	15.91	2.90	26.02
14.000	5.554	5.59	38.53	5.52	49.57	33.000	13.091	2.19	15.12	2.81	25.25
15.000	5.950	5.04	34.77	5.22	46.89	34.000	13.488	2.08	14.33	2.73	24.50
16.000	6.347	4.63	31.95	4.97	44.59	35.000	13.884	1.96	13.53	2.65	23.77
17.000	6.744	4.32	29.77	4.75	42.60	36.000	14.281	1.85	12.73	2.57	23.06
18.000	7.141	4.07	28.05	4.55	40.84	37.000	14.678	1.73	11.95	2.49	22.36
19.000	7.537	3.87	26.65	4.38	39.26	38.000	15.075	1.62	11.17	2.42	21.68
20.000	7.934	3.69	25.48	4.22	37.83	39.000	15.471	1.51	10.41	2.34	21.01
21.000	8.331	3.55	24.46	4.07	36.52	40.000	15.868	1.40	9.67	2.27	20.36

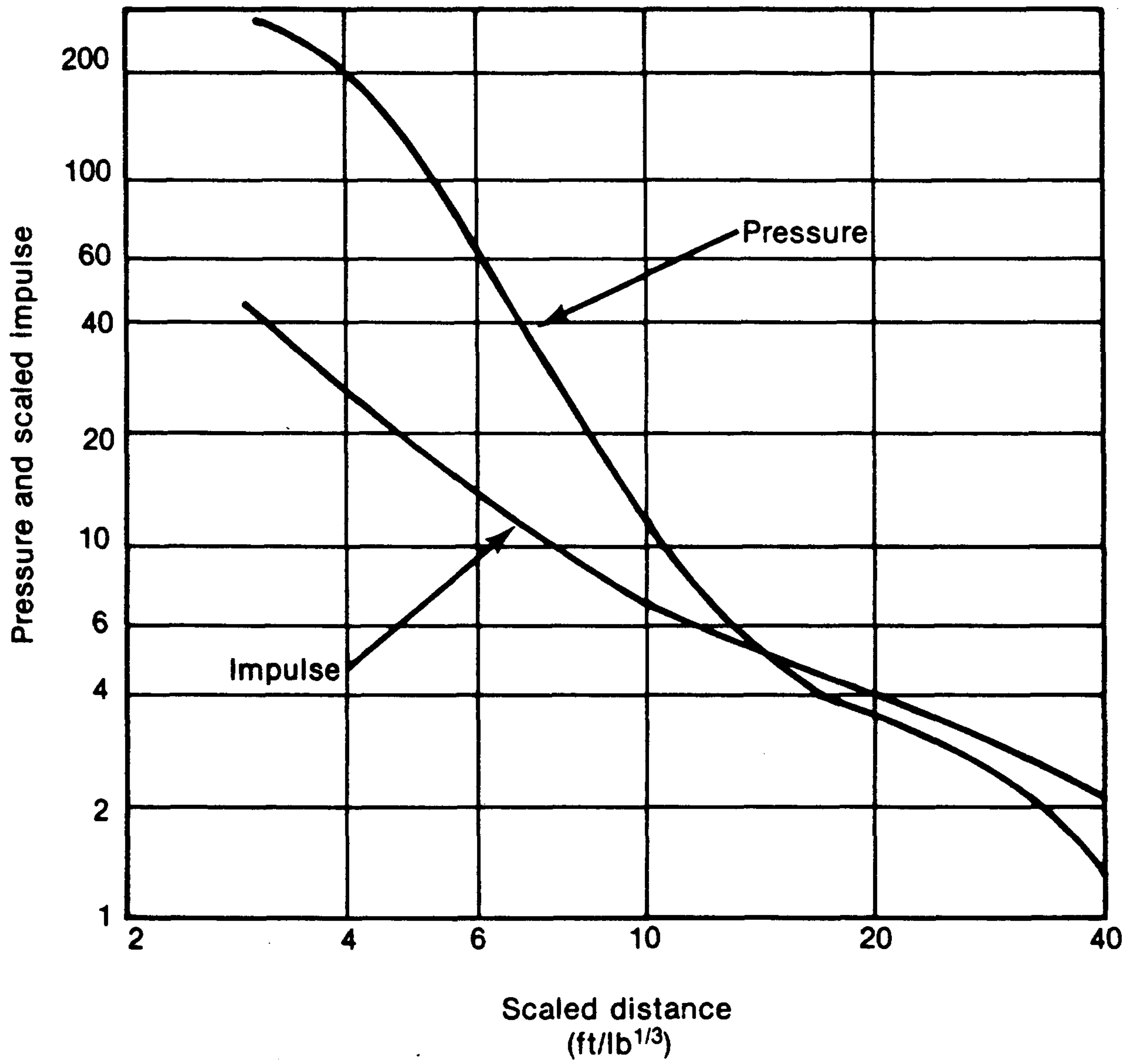


Figure 51. Pressure and Impulse Versus Scale Distance for Composition A5 in Cylindrical Containers L/D=1.6:1.

COMPOSITION B[3]

OBJECTIVE

The primary test objectives were to measure the pressure-time-distance relationships for surface bursts of cast Composition B and to study the effects of shaped charges. Included in this study were spheres, hemispheres, and cylinders in an enclosed cubicle.

MATERIAL

Composition B is a mixture of RDX and TNT (60/40%, respectively) with 1% wax added. It is prepared by adding wet RDX to molten TNT stirred until the moisture is driven off and then the wax is added. It is cooled to a satisfactory pouring temperature and cast directly into ammunition components. It may also be found in bulk form such as chips. The density of Composition B is 1.65 g/cm^3. Composition B charges were cast and machined to accept a J2 engineers' special blasting cap. The spherical charges were cast with a 22 gram spherical Pentolite booster centered in the sphere. Charge weights of the hemispherical charges were 0.45 and 1.34 kg (1 and 2.95 lb). Spherical charge weights were 0.49 and 1.22 kg (1.07 and 2.69 lb). Cylindrical charge weights were 0.68 and 1.37 kg (1.49 and 3.03 lb).

TEST SETUP

Hemispherical Composition B charges were detonated directly on sand and on a steel witness plate to determine which condition produced the most consistent results for surface bursts. The test results indicated that the steel witness plate should be used on all subsequent testing.

Spherical Composition B surface bursts tests were run for comparison with known TNT results. Airblast parameters for cylindrical Composition B surface bursts were measured and used for evaluating shape and elevation effects.

INSTRUMENTATION

Piezoresistive pressure transducers manufactured by Tyco Instrument Division of Bytrex, Inc. were used for the pressure and impulse measurements. The HFG series gage used is specifically designed to measure blast phenomena in a field situation. The gage is supplied with an integral heat and debris shield with eight equally spaced holes 1.016 mm (0.04 inch) diameter leading to the gage diaphragm. The filter provides a cylindrical air space above the diaphragm of 0.254 mm (0.01 inch). The diameter of the space varies with the pressure range of the gage. Gages designed to measure peak pressure of 103, 172, 1379, 3448, and 6895 kPa (15, 25, 100, 200, 500, and 1000 psi) were placed along the gage line in accordance with the predicted pressure at the gage location. Gages were statically calibrated with air pressure at about the level of the anticipated peak shock pressure.

In the beginning of the test program, a nominal 20-kHz recording system was used. This system consisted of Endevco models 4401 and 4470 signal conditioners, Dana models 3850V2 and 4472-6 amplifiers, and a Sangamo Saber 4 tape recorder at 60 ips. This system was used for the hemispherical test and a portion of the elevated cylinder tests.

A nominal 40-kHz recording system was used for the remaining tests. This system substituted Minneapolis-Honeywell model 104 amplifiers and increased the tape recording speed to 120 ips.

The FM signal data was digitized by the data reduction facility at the Pacific Missile Range. The 20-kHz pressure-time data was digitized at 160 samples/ms (6.25 s per data point). The 40-kHz data digitizing rate was doubled to 320 samples/ms (3.125 s per data point).

The pressure transducers were arranged in a 90 degree array 0.61, 1.22, 2.44, 4.88, 9.75, and 15.24 m (2, 4, 8, 16, 32, and 50 ft). The radial distance was held constant throughout the test series.

RESULTS

The results of the peak pressure and scaled positive impulse measurements for hemispherical Composition B are given in Table 4 and plotted in Figure 52. Table 5 shows the results of the spherical Composition B tests. The plotted values are shown in Figure 53. The cylindrical cast charges test results are given in Table 6 and are plotted in Figure 54.

DISCUSSION

Hemispherical Composition B tests were conducted on a sand surface and a steel witness plate. Generally the data from those tests conducted on the sand, were lower than the values that were detonated atop a steel witness plate at the near-field values (scaled distances equal to or less than 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1.3}$)), nearly the same as expected at scaled distances between 8.73 and 15.87 $m/kg^{1/3}$ (22 and 40 $ft/lb^{1/3}$). Impulse values followed the same general trend.

Spherical test results show that the pressure and scaled positive impulse values were generally greater than the hemispherical results and approximately the same as the cylindrical results.

Cylindrical test results were generally greater than the hemispherical tests at all selected scaled distances, and nearly the same as the values achieved for the spherical tests at all scaled distances.

CONCLUSIONS

(1) Blast overpressure and scaled positive impulse for hemispherical Composition B with a L/D ratio equal to 1:1 were generally equivalent to those of equal amounts of TNT at the same scaled distances of the experiments.

(2) Blast overpressure and scaled positive impulse were generally greater than those values obtained on hemispherical

Composition B at all scaled distances.

(3) Blast overpressure and scaled positive impulse values for cylindrical Composition B with a L/D ratio equal to 1:1 were generally greater than those values obtained for hemispherical Composition B at the same scaled distances. Cylindrical values were approximately the same as the spherical data at all scaled distances.

(4) Charge shape effect for the surface burst were substantial at scaled distances equal to or less than 7.9 m/kg$^{1/3}$ (20 ft/lb$^{1/3}$). Charge shape effects should be considered at scaled distances less than 7.9 m/kg$^{1/3}$ (20 ft/lb$^{1/3}$).

Table 4. Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse Values for Composition B, Hemispherical L/D = 1:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{\text{psi}\cdot\text{ms}}{\text{lb}^{1/3}}$	Scaled Impulse $\frac{\text{kPa}\cdot\text{ms}}{\text{kg}^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{\text{psi}\cdot\text{ms}}{\text{lb}^{1/3}}$	Scaled Impulse $\frac{\text{kPa}\cdot\text{ms}}{\text{kg}^{1/3}}$
3.000	1.190	102.89	709.42	16.04	143.94	22.000	8.727	2.42	16.69	3.50	31.40
4.000	1.587	58.90	406.11	14.00	125.65	23.000	9.124	2.27	15.64	3.35	30.09
5.000	1.983	37.71	260.01	12.27	110.07	24.000	9.521	2.14	14.72	3.22	28.89
6.000	2.380	26.11	180.00	10.84	97.29	25.000	9.917	2.02	13.92	3.10	27.79
7.000	2.777	19.14	131.96	9.68	86.83	26.000	10.314	1.91	13.20	2.98	26.77
8.000	3.174	14.66	101.07	8.71	78.20	27.000	10.711	1.82	12.56	2.88	25.82
9.000	3.570	11.66	80.12	7.91	71.00	28.000	11.108	1.74	11.99	2.78	24.94
10.000	3.967	9.47	65.30	7.24	64.93	29.000	11.504	1.67	11.48	2.69	24.12
11.000	4.364	7.89	54.43	6.66	59.76	30.000	11.901	1.60	11.02	2.60	23.36
12.000	4.760	6.71	46.25	6.16	55.31	31.000	12.298	1.54	10.61	2.52	22.65
13.000	5.157	5.79	39.93	5.73	51.45	32.000	12.694	1.48	10.23	2.45	21.98
14.000	5.554	5.07	34.95	5.36	48.07	33.000	13.091	1.43	9.89	2.38	21.35
15.000	5.950	4.49	30.95	5.03	45.10	34.000	13.488	1.39	9.57	2.31	20.76
16.000	6.347	4.02	27.70	4.73	42.46	35.000	13.884	1.35	9.29	2.25	20.21
17.000	6.744	3.63	25.02	4.47	40.11	36.000	14.281	1.31	9.03	2.19	19.68
18.000	7.141	3.30	22.77	4.23	38.00	37.000	14.678	1.27	8.79	2.14	19.19
19.000	7.537	3.03	20.88	4.02	36.10	38.000	15.075	1.24	8.57	2.09	18.72
20.000	7.934	2.79	19.27	3.83	34.38	39.000	15.471	1.21	8.36	2.04	18.28
21.000	8.331	2.59	17.88	3.66	32.82	40.000	15.868	1.19	8.18	1.99	17.86

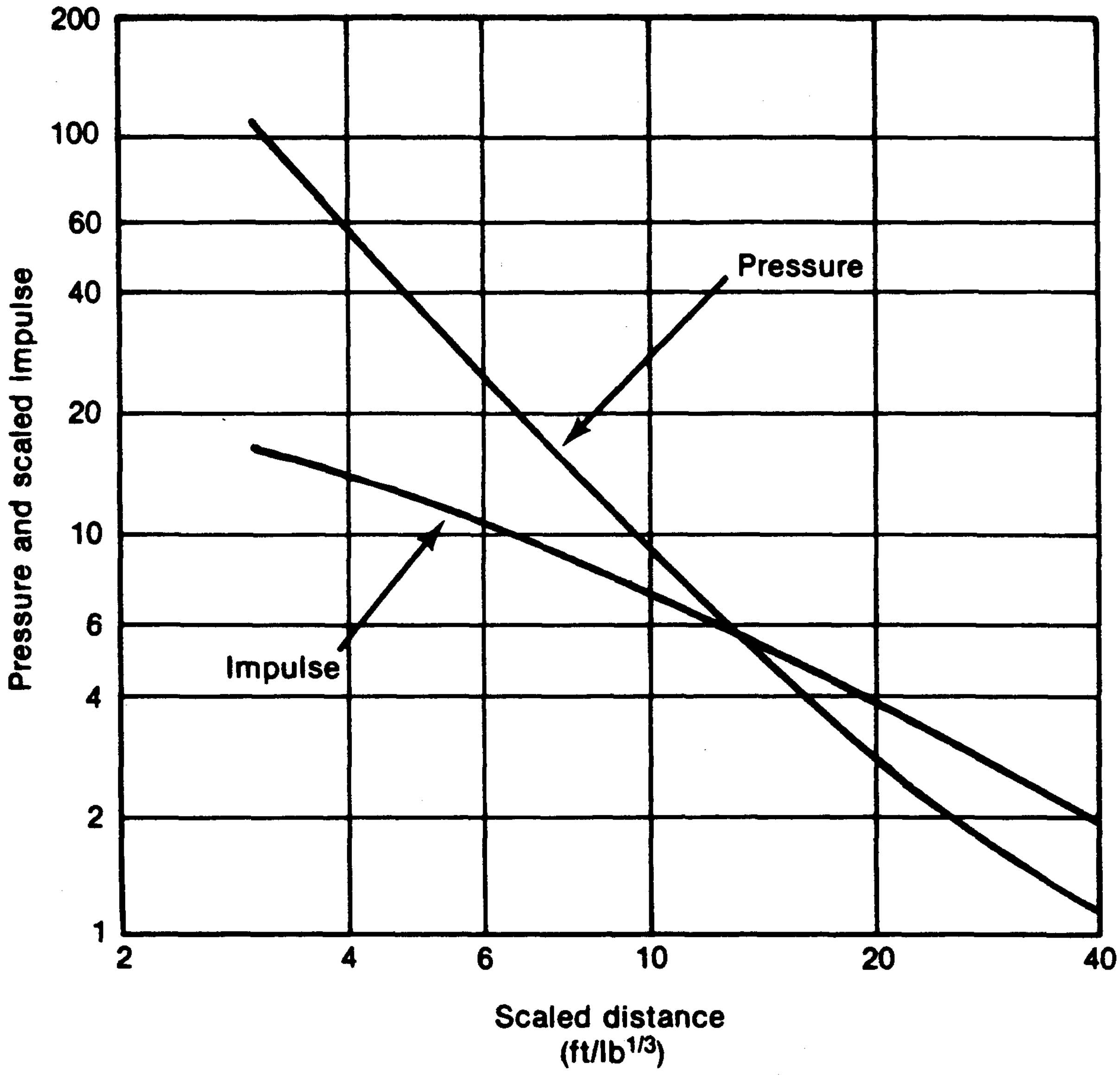


Figure 52. Pressure and Impulse Versus Scaled Distance for Hemispherical Composition B, L/D = 1:1.

Table 5. Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse Values for Cast Spherical Composition B, L/D = 1:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	228.63	1576.41	42.14	378.18	22.000	8.727	2.77	19.09	4.60	41.28
4.000	1.587	110.92	764.77	31.81	285.50	23.000	9.124	2.58	17.80	4.40	39.47
5.000	1.983	62.47	430.75	24.30	218.05	24.000	9.521	2.42	16.66	4.21	37.78
6.000	2.380	39.34	271.27	19.25	172.73	25.000	9.917	2.27	15.64	4.03	36.19
7.000	2.777	26.92	185.58	15.80	141.83	26.000	10.314	2.14	14.73	3.87	34.70
8.000	3.174	19.60	135.13	13.38	120.04	27.000	10.711	2.02	13.91	3.71	33.28
9.000	3.570	14.97	103.23	11.60	104.12	28.000	11.108	1.91	13.16	3.56	31.93
10.000	3.967	11.87	81.87	10.26	92.12	29.000	11.504	1.81	12.48	3.42	30.65
11.000	4.364	9.70	66.90	9.23	82.79	30.000	11.901	1.72	11.86	3.28	29.42
12.000	4.760	8.12	56.01	8.40	74.35	31.000	12.298	1.64	11.29	3.15	28.24
13.000	5.157	6.94	47.83	7.72	69.29	32.000	12.694	1.56	10.76	3.02	27.11
14.000	5.554	6.02	41.52	7.16	64.24	33.000	13.091	1.49	10.27	2.90	26.03
15.000	5.950	5.30	36.54	6.68	59.97	34.000	13.448	1.42	9.81	2.78	24.98
16.000	6.347	4.72	32.53	6.27	56.28	35.000	13.884	1.36	9.38	2.67	23.98
17.000	6.744	4.24	29.24	5.91	53.06	36.000	14.281	1.30	8.99	2.56	23.01
18.000	7.141	3.85	26.51	5.60	50.21	37.000	14.678	1.25	8.61	2.46	22.08
19.000	7.537	3.51	24.21	5.31	47.66	38.000	15.075	1.20	8.26	2.36	21.18
20.000	7.934	3.23	22.25	5.05	45.34	39.000	15.471	1.15	7.93	2.26	20.31
21.000	8.331	2.98	20.56	4.82	43.23	40.000	15.868	1.10	7.62	2.17	19.47

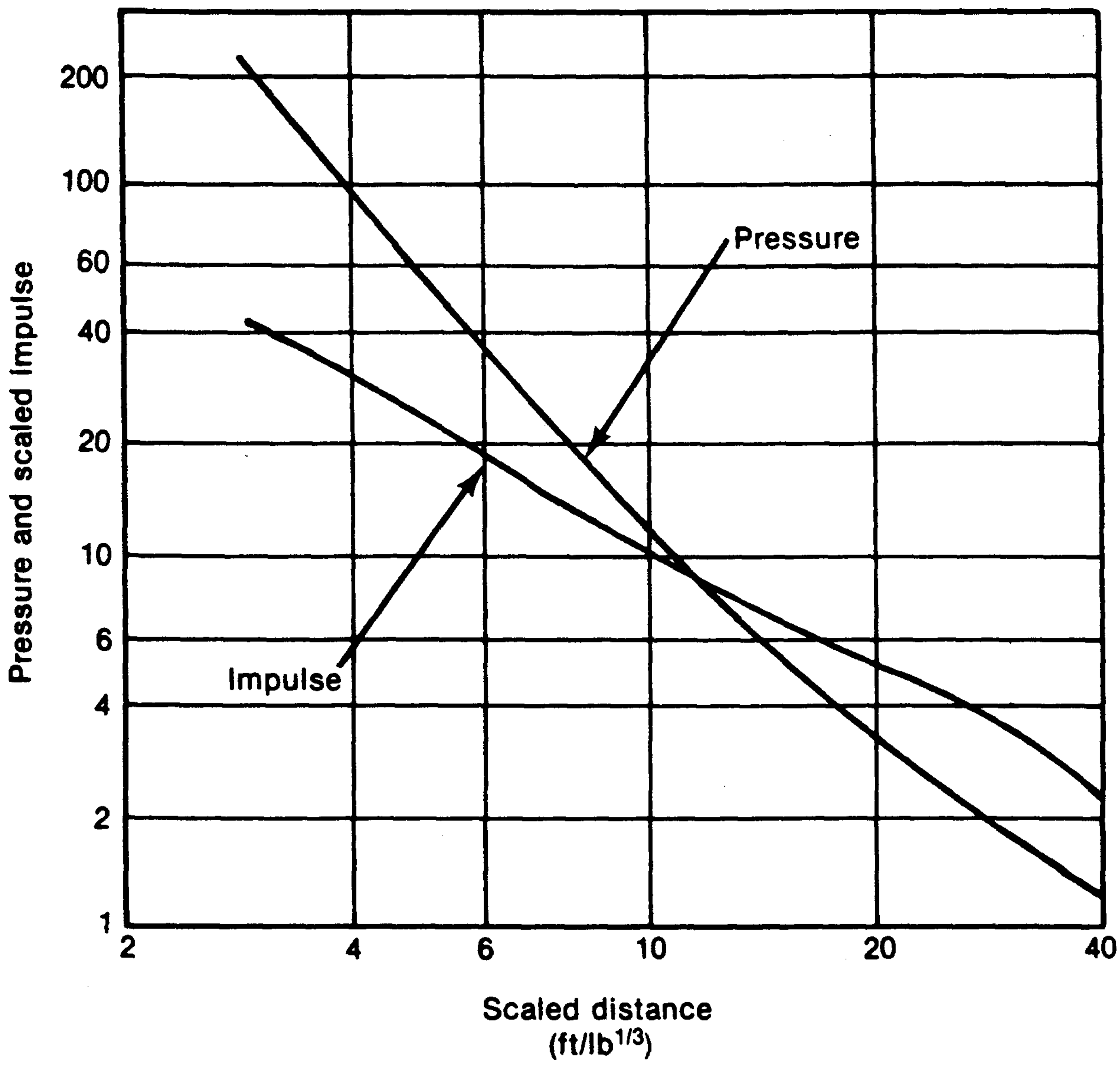


Figure 53. Pressure and Impulse Versus Scaled Distance for Spherical Composition B, L/D = 1:1.

Table 6. Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse Values for Composition B, Cylindrical L/D = 1:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	230.11	1586.59	33.65	302.01	22.000	8.727	2.48	17.10	3.64	32.64
4.000	1.587	113.03	779.33	25.51	228.93	23.000	9.124	2.30	15.83	3.50	31.43
5.000	1.983	64.31	443.40	19.25	172.77	24.000	9.521	2.13	14.72	3.38	30.29
6.000	2.380	40.67	280.43	15.04	134.96	25.000	9.917	1.99	13.74	3.26	29.22
7.000	2.777	27.80	191.67	12.20	109.47	26.000	10.314	1.87	12.87	3.14	28.21
8.000	3.174	20.15	138.91	10.23	91.79	27.000	10.711	1.75	12.09	3.04	27.25
9.000	3.570	15.28	105.32	8.81	79.10	28.000	11.108	1.65	11.39	2.93	26.33
10.000	3.967	12.00	82.77	7.77	69.68	29.000	11.504	1.56	10.76	2.84	25.44
11.000	4.364	9.71	66.94	6.96	62.50	30.000	11.901	1.48	10.19	2.74	24.59
12.000	4.760	8.04	55.43	6.34	56.87	31.000	12.298	1.40	9.67	2.65	23.77
13.000	5.157	6.79	46.80	5.83	52.36	32.000	12.694	1.33	9.20	2.56	22.98
14.000	5.554	5.83	40.16	5.42	48.67	33.000	13.091	1.27	8.77	2.47	22.21
15.000	5.950	5.07	34.95	5.08	45.58	34.000	13.488	1.21	8.37	2.39	21.46
16.000	6.347	4.46	30.78	4.79	42.96	35.000	13.884	1.16	8.00	2.31	20.73
17.000	6.744	3.97	27.38	4.54	40.70	36.000	14.281	1.11	7.66	2.23	20.02
18.000	7.141	3.57	24.58	4.32	38.72	37.000	14.678	1.06	7.34	2.15	19.33
19.000	7.537	3.23	22.24	4.12	36.97	38.000	15.075	1.02	7.05	2.08	18.66
20.000	7.934	2.94	20.25	3.94	35.39	39.000	15.471	0.98	6.77	2.01	18.00
21.000	8.331	2.69	18.56	3.78	33.96	40.000	15.868	0.94	6.52	1.93	17.36

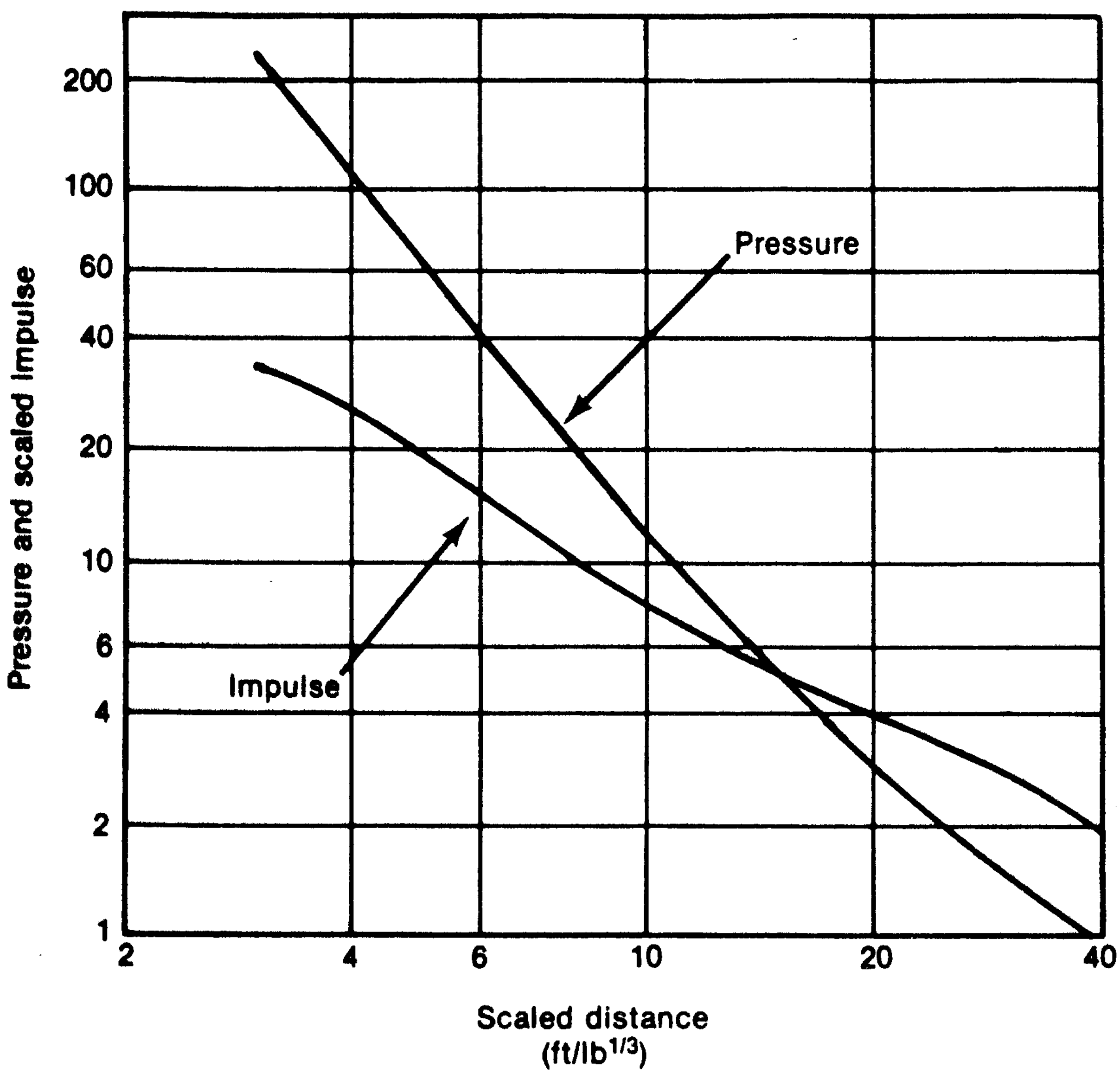


Figure 54. Pressure and Impulse Versus Scaled Distance for Cylindrical Composition B, L/D = 1:1.

COMPOSITION C4[7]

OBJECTIVE

The objective of this study was to determine the peak pressure and positive impulse resulting from the detonation of both bulk and extruded Composition C4 in standard shipping containers and dryer bed configurations. Test results were compared to standard hemispherical TNT data to determine the TNT equivalency of Composition C4.

MATERIAL

Composition C4 is composed of 91% RDX and 9% plasticizer (nonexplosive). The plasticizer contains 2.1% polyisobutylene, 1.6% motor oil, and 5.3% DI(2-ethylexyl) sebacate. It is a white puttylike plastic explosive that can be pressed or extruded into the desired shapes. The reported density for Composition C4 ranges from 1.52 to 1.61 g/cm^3. The reported detonation velocity is 8040 m/s at 1.59 g/cm^3.

The Composition C4 for this test series was received in bulk quantities of 27.2 kg (60 lb) in fiberboard shipping containers and M112 extruded demolition blocks in wirebound wooden boxes, 30 blocks per box, with a total explosive weight of 17 kg (37.5 lb).

TEST SETUP

Airblast output was evaluated for mass weights of Composition C4 in two shipping containers and a scaled in-plant dryer bed configuration. Physical characteristics of the test items were as follows:

(1) Extruded M112 Demolition Blocks in the orginal shipping container was placed on a 45.7 x 45.7 x 1.27 cm (18 x 18 x 1.27 inches) steel witness plate and tested.

(2) Bulk Composition C4 in its orginal fiberboard shipping container was placed on a 45.7 x 45.7 x 1.27 cm (18 x 18 x 0.5 inches) steel witness plate and tested.

(3) An orthorhombic plywood container with dimensions of 91.4 x 91.4 x 10.16 cm (36 x 36 x 4 inches) was used. Composition C4 with a charge weight of 63.5 kg (140 lb) was placed inside and spread evenly, then the lid was put in place.

A J2 engineers' special blasting cap was inserted in the center of a conical-shaped booster charge and placed atop the test materials and initiated. The booster charge had a height to diameter ratio of 1:2 for the 17 and 27.2 kg (37.5 and 60 lb) charge weights and, a height to diameter ratio of 1:4 was used for the dryer bed tests.

INSTRUMENTATION

Twelve PCB Piezoelectric side-on pressure transducers were mounted flush to the surface in a 90-degree array. Radial distances from the charge to the transducers correspond to scaled distances from 1.19 to 15.87 m/kg$^{1/3}$ (3.0 to 40.0 ft/lb$^{1/3}$).

TEST RESULTS

Combined test results of 17 and 27.2 kg (37.5 and 60 lb) charges in an orthorhombic configuration with a L/D ratio of 0.5:1 are shown in Table 7 and Figure 55. The dryer bed configuration tests results are given in Table 8 and Figure 56.

DISCUSSION

The results for the M112 Demolition Blocks and the bulk explosives in the standard shipping container were combined. The height to length ratio for both configurations were 0.5:1. The peak pressure values were greater than expected at all scaled distances of the experiment with the exception of a scaled distance of 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$) where the pressure value was slightly less than the expected value. Pressure values were 2525, 1185, 514, 123, 24, and 10 kPa (366.24, 172.00, 74.51, 17.90, 3.39, and 1.46 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0 and 40 ft/lb$^{1/3}$), respectively. These values equate to 3.07, 3.25, 3.15, 1.56, 0.92, and 1.42 times equal amounts of TNT at the same scaled distances, respectively. Impulse values for the combined values were less than expected at scaled distances of 1.19, 3.57, and 7.14 m/kg$^{1/3}$ (3.0, 9.0, and 18.0 ft/lb$^{1/3}$) and greater than expected at scaled distances of 1.59, 2.14, and 15.87 m/kg$^{1/3}$ (4.0, 5.4, and 40 ft/lb$^{1/3}$). The scaled positive impulse values were 325, 205, 132, 69, 35, and 22 kPa-ms/kg$^{1/3}$ (36.17, 22.79, 14.7, 7.71, 3.94, and 2.43 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These values equate to 0.96, 1.16, 1.61, 0.72, 0.85, and 2.13 times equal amounts of TNT at the same scaled distances, respectively.

Dryer bed results with a height to length ratio of 0.01:1 were different than those obtained in the orthorhombic configuration with a height to length ratio of 0.5:1. The pressure values were greater than expected at scaled distances of 1.19, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 9.0, 18.0, and 40 ft/lb$^{1/3}$) and less than expected at scaled distances of 1.59 and 2.14 m/kg$^{1/3}$ (4.0 and 5.4 ft/lb$^{1/3}$). The pressure values were 1001, 465, 185, 69, 38, and 12 kPa (145.18, 67.50, 26.77, 9.98, 5.56, and 1.78 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14 and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These values equate to 1.18, 0.92, 0.70, 1.56, 2.39, and 2.58 times equal amounts of TNT at the same scaled distances, respectively. Impulse values were greater than expected at scaled distances of 7.14 and 15.87 m/kg$^{1/3}$ (18.0 and 40.0 ft/lb$^{1/3}$) and less than expected at scaled distances of 1.19, 1.59, 2.14, and 3.57 m/kg$^{1/3}$ (3.0, 4.0, 5.4, and 9.0 ft/lb$^{1/3}$). The scaled positive impulse values were 113, 88, 80, 76, 46, and 23 kPa-ms/kg$^{1/3}$ (12.57, 9.80, 8.96, 8.43, 5.09, and 2.51 psi-ms/lb$^{1/3}$), respectively. These values equate to 0.50, 0.59, 0.51, 0.55, 1.37, and 1.41 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) Pressure values for Composition C4 in orthorhombic shipping containers with a height to length ratio of 0.5:1 were greater than expected at all scaled distances of the experiment with the exception at a scaled distance of 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$).

(2) Scaled positive impulse values for Composition C4 in standard orthorhombic shipping containers were greater than expected at scaled distances of 1.57, 2.14 and 15.87 $m/kg^{1/3}$ (4.0, 5.4 and 40.0 $ft/lb^{1/3}$) and less than expected at scaled distances of 1.19, 3.57 and 7.14 $m/kg^{1/3}$ (3.0, 9.0 and 18 $ft/lb^{1/3}$).

(3) Pressure values for Composition C4 in the dryer bed configuration with a height to length ratio of 0.1:1 were greater than expected at scaled distances of 1.19, 3.57, 7.14 and 15.87 $m/kg^{1/3}$ (3.0, 9.0, 18.0 and 40.0 $ft/lb^{1/3}$) and less than expected at scaled distances of 1.59 and 2.14 $m/kg^{1/3}$ (4.0 and 5.4 $ft/lb^{1/3}$).

(4) Scaled positive impulse values for Composition C4 in the dryer bed configuration were less than expected at scaled distances of 1.19, 1.59, 2.14 and 3.57 $m/kg^{1/3}$ (3.0, 4.0, 5.4 and 9.0 $ft/lb^{1/3}$) and greater than expected at scaled distances of 7.14 and 15.87 $m/kg^{1/3}$ (18.0 and 40.0 $ft/lb^{1/3}$).

(5) Pressure and scaled positive impulse values of Composition C4 in standard orthorhombic shipping containers and dryer bed configurations are dependent upon geometry.

Table 7. Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse Values for Composition C4, Orthorhombic L/D = 0.5:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	366.24	2525.24	36.17	324.57	22.000	8.727	2.47	17.02	3.39	30.39
4.000	1.587	172.00	1185.96	22.79	204.51	23.000	9.124	2.31	15.92	3.28	29.47
5.000	1.983	92.58	638.32	16.38	146.96	24.000	9.521	2.17	14.99	3.19	28.65
6.000	2.380	55.30	381.31	12.73	114.24	25.000	9.917	2.06	14.20	3.11	27.90
7.000	2.777	35.80	246.83	10.42	93.51	26.000	10.314	1.96	13.52	3.03	27.22
8.000	3.174	24.68	170.18	8.84	79.36	27.000	10.711	1.88	12.94	2.96	26.60
9.000	3.570	17.90	123.42	7.71	69.16	28.000	11.108	1.81	12.45	2.90	26.03
10.000	3.967	13.53	93.27	6.85	61.51	29.000	11.504	1.74	12.02	2.84	25.51
11.000	4.364	10.58	72.94	6.19	55.58	30.000	11.901	1.69	11.65	2.79	25.03
12.000	4.760	8.51	58.71	5.67	50.86	31.000	12.298	1.64	11.34	2.74	24.59
13.000	5.157	7.02	48.42	5.24	47.03	32.000	12.694	1.61	11.07	2.70	24.19
14.000	5.554	5.91	40.78	4.89	43.87	33.000	13.091	1.57	10.84	2.65	23.81
15.000	5.950	5.07	34.97	4.59	41.21	34.000	13.488	1.54	10.65	2.61	23.46
16.000	6.347	4.42	30.47	4.34	38.95	35.000	13.884	1.52	10.49	2.58	23.14
17.000	6.744	3.90	26.92	4.12	37.01	36.000	14.281	1.50	10.36	2.54	22.83
18.000	7.141	3.49	24.08	3.94	35.33	37.000	14.678	1.49	10.25	2.51	22.55
19.000	7.537	3.16	21.78	3.77	33.86	38.000	15.075	1.47	10.17	2.48	22.29
20.000	7.934	2.88	19.89	3.63	32.57	39.000	15.471	1.47	10.11	2.40	22.04
21.000	8.331	2.66	18.32	3.50	31.42	40.000	15.868	1.46	10.07	2.43	21.81

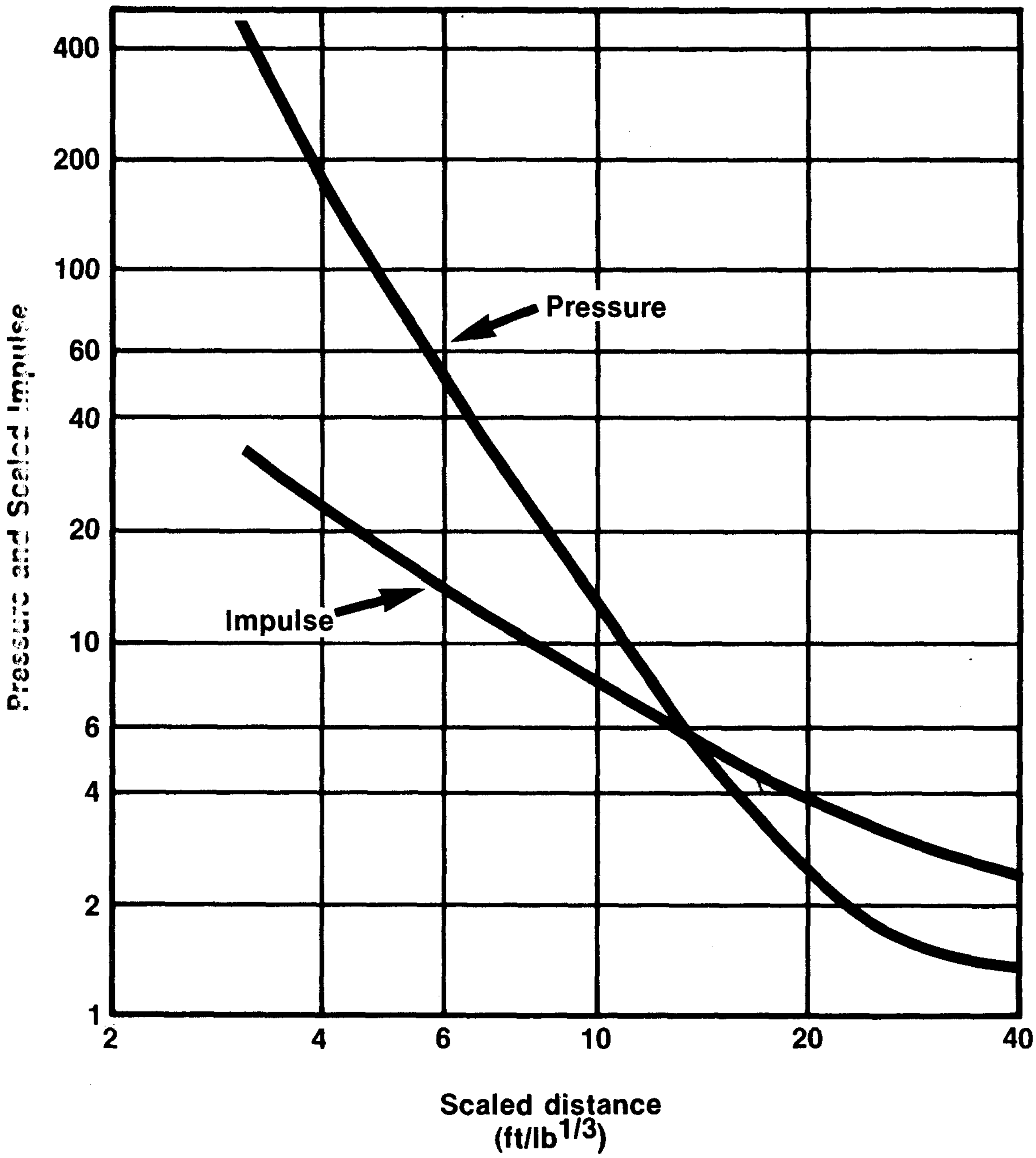


Figure 55. Pressure and Impulse Versus Scaled Distance for Orthorhombic Composition C4, L/D = 0.5:1.

Table 8. Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse Values for Composition C4, Orthorhombic L/D = 0.1:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	145.18	1000.98	12.57	112.79	22.000	8.727	5.61	38.68	4.13	37.09
4.000	1.587	67.50	465.38	9.80	87.83	23.000	9.124	5.54	38.21	3.94	35.37
5.000	1.983	33.79	233.00	9.09	81.57	24.000	9.521	5.44	37.53	3.77	33.81
6.000	2.380	19.76	136.24	8.83	79.25	25.000	9.917	5.32	36.66	3.61	32.40
7.000	2.777	13.29	91.62	8.65	77.59	26.000	10.314	5.16	35.59	3.47	31.11
8.000	3.174	9.98	68.80	8.43	75.63	27.000	10.711	4.98	34.35	3.34	29.95
9.000	3.570	8.15	56.17	8.16	73.20	28.000	11.108	4.78	32.94	3.22	28.89
10.000	3.967	7.08	48.80	7.84	70.34	29.000	11.504	4.55	31.38	3.11	27.94
11.000	4.364	6.44	44.38	7.49	67.19	30.000	11.901	4.31	29.71	3.02	27.09
12.000	4.760	6.05	41.73	7.12	63.90	31.000	12.298	4.05	27.95	2.93	26.33
13.000	5.157	5.83	40.19	6.75	60.57	32.000	12.694	3.79	26.13	2.86	25.64
14.000	5.554	5.71	39.36	6.38	57.30	33.000	13.091	3.52	24.28	2.79	25.03
15.000	5.950	5.65	38.98	6.03	54.14	34.000	13.488	3.25	22.41	2.73	24.50
16.000	6.347	5.64	38.89	5.70	51.14	35.000	13.884	2.98	20.57	2.68	24.02
17.000	6.744	5.65	38.94	5.38	48.32	36.000	14.281	2.72	18.76	2.63	23.61
18.000	7.141	5.66	39.04	5.09	45.70	37.000	14.678	2.47	17.02	2.59	23.26
19.000	7.537	5.67	39.12	4.82	43.26	38.000	15.075	2.23	15.34	2.56	22.96
20.000	7.934	5.67	39.11	4.57	41.02	39.000	15.471	2.00	13.76	2.53	22.70
21.000	8.331	5.65	38.98	4.34	38.97	40.000	15.868	1.78	12.26	2.51	22.50

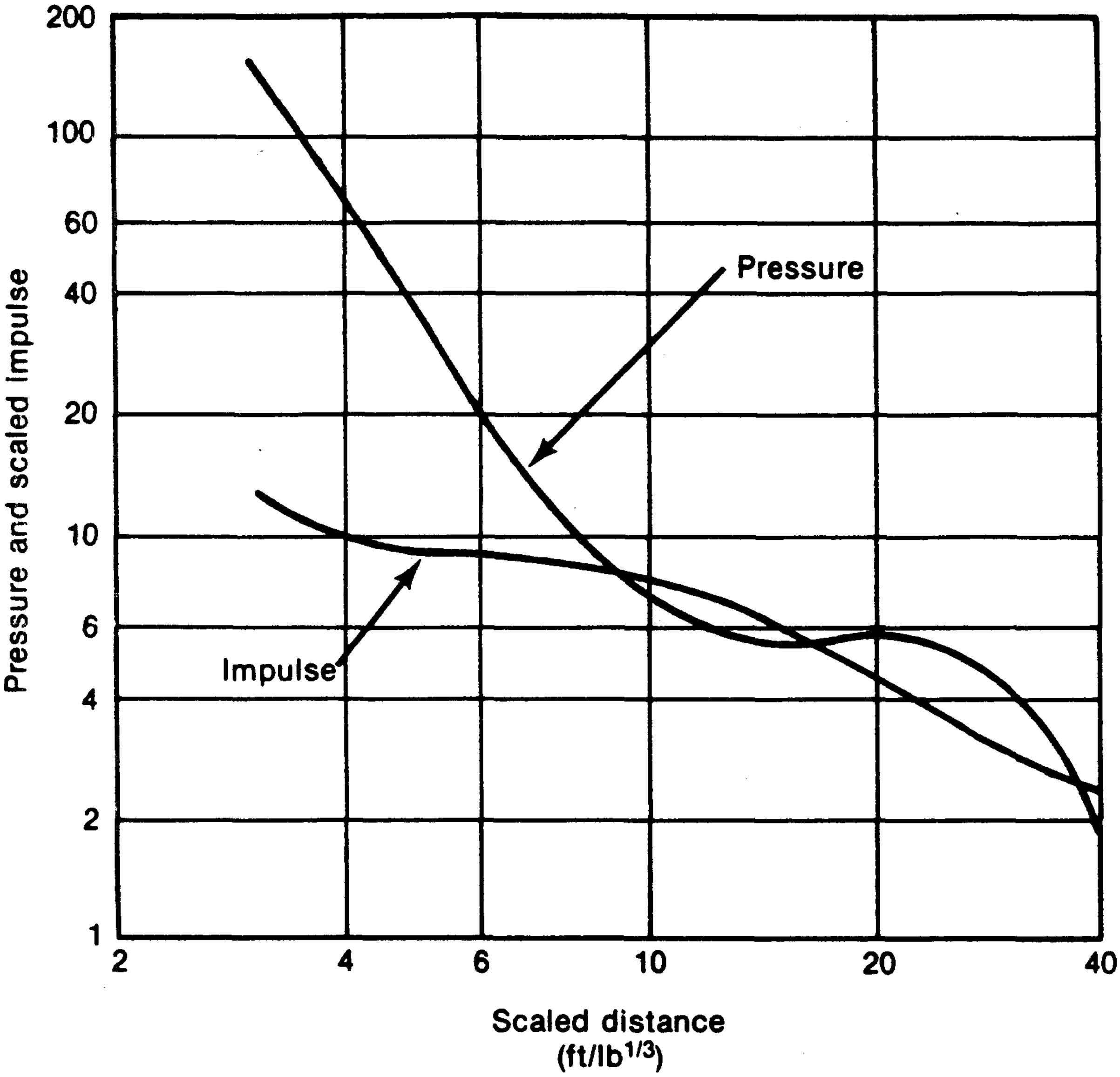


Figure 56. Pressure and Impulse Versus Scaled Distance for Orthorhombic Composition C4, L/D = 0.01:1.

CYCLOTOL 70/30[8]

OBJECTIVE

The objective of this study was to determine the maximum output from the detonation of Cyclotol 70/30 high explosives in terms of peak pressure and positive impulse in three configurations simulating in-plant processing and shipping containers. The measured pressure and positive impulse values were compared to hemispherical TNT data to determine the equivalency of Cyclotol relative to TNT.

MATERIAL

Cyclotol 70/30, Type II, Class A, prepared in a similar manner as Composition B, is a castable high explosive used primarily as a munition filler. Cyclotol 70/30 has a loading density of 1.71 g/cm^3 and a detonation velocity of 8060 m/s at a density of 1.73 g/cm^3. Cyclotol was received in 27.2 kg (60 lb) telescoping fiberboard shipping containers in the form of chips.

TEST SETUP

Airblast output was evaluated for weights of Cyclotol 70/30 representing bulk chips of Cyclotol in a standard orthorhombic shipping container, an orthorhombic transfer box and a truncated prism representing a hopper. Physical characteristics of the test items were:

(1) A standard orthorhombic shipping container with a linear dimensional scaling factor of 0.79 and in a full-scale shipping container filled with 13.6 and 27.2 kg (30 and 60 lb) respectively.

(2) An orthorhombic fiberboard transfer box with dimensional scaling factors of 0.41 and 0.47 filled with 45.4 and 68.0 kg (100 and 150 lb) respectively.

(3) A wooden truncated prism simulating a hopper with dimensional scaling factors of 0.73 and 0.84 filled with 45.4 and 60.0 kg (100 and 150 lb), respectively.

All test charges representing all configurations were placed on a 1010 carbon steel witness plate 1.27 cm (0.5 inch) thick with dimensions being at least 5.08 cm (2 inch) larger than the base of the configuration dimensions.

A Composition C4, conical-shaped booster charge, with a height to diameter ratio of 1:2 was centered on top of the test charge for the orthorhombic configurations. A height to diameter ratio of 1:4 was used for the truncated prism configuration. A J2 engineers' special blasting cap was used as the initiation source.

INSTRUMENTATION

Twelve Piezoelectric side-on pressure transducers were mounted flush to the surface in a 90-degree array. Radial distances from the charge to the transducers correspond to scaled distances from 1.19 to 15.87 $m/kg^{1/3}$ (3.0 to 40 $ft/lb^{1/3}$).

TEST RESULTS

All orthorhombic configuration test results were combined and the results of the combined values are given in Table 9 and Figure 57. The results of the truncated prism in-process hopper configuration results are given in Table 10 and Figure 58.

DISCUSSION

Peak pressure values were greater than expected at all scaled distances of the experiment. The pressure values were 2810, 1358, 541, 115, 26, and 10 kPa (407.5, 196.9, 78.4, 16.7, 3.8, and 1.5 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These values equate to 4.6, 4.1, 2.9, 1.6, 1.2, and 1.7 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were equal to or greater than the expected values at all scaled distances. The scaled positive impulse values were 343, 230, 151, 77, 36, and 17 $kPa\text{-}ms/kg^{1/3}$ (38.2, 25.6, 16.8, 8.6, 4.0, and 1.9 $psi\text{-}ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These values equate to 3.2, 2.4, 1.9, 1.2, 1.0, and 1.0 times equal amounts of TNT at the same scaled distances. respectively.

The results of the truncated prism were greater than or equal to the expected values at all scaled distances. At the near-field values the pressure levels were greater than those obtained during the orthorhombic test configuration and nearly the same or slightly less at the far-field distances. The pressure values were 3716, 2550, 949, 141, 31, and 8 kPa (538.9, 369.9, 137.7, 20.4, 4.5, and 1.18 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These values equate to 6.7, 10, 6.0, 2.2, 1.6, and 1.0 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were greater than expected at all scaled distances with the exception at a scaled distance of 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$). The scaled positive impulse values were 328, 302, 212, 85, 24, and 19 $kPa\text{-}ms/kg^{1/3}$ (37.7, 33.7, 23.6, 9.5, 2.7, and 2.1 $psi\text{-}ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These values equate to 3.4, 3.5, 3.5, 1.2, 0.6, and 1.1 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) Cyclotol 70/30, when detonated, can generate peak pressure and scaled positive impulse that are greater than those produced by equal amounts of TNT.

(2) The blast output from Cyclotol 70/30 is dependent upon the configuration from which it detonates.

(3) To within experimental limits, blast pressure and impulse scale as a cube root function of the charge weight.

Table 9. Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse Values for Cyclotol 70/30 in Orthorhombic Configuration, L/D = 0.64:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	407.47	2809.53	38.16	342.44	22.000	8.727	2.92	20.15	3.35	30.05
4.000	1.587	196.98	1358.16	25.63	230.00	23.000	9.124	2.77	19.11	3.22	28.87
5.000	1.983	99.99	689.43	18.74	168.16	24.000	9.521	2.64	18.20	3.10	27.80
6.000	2.380	56.14	387.11	14.57	130.74	25.000	9.917	2.52	17.40	2.99	26.81
7.000	2.777	34.70	239.29	11.85	106.32	26.000	10.314	2.42	16.67	2.89	25.89
8.000	3.174	23.26	160.39	9.96	89.42	27.000	10.711	2.32	16.02	2.79	25.05
9.000	3.570	16.66	114.86	8.60	77.16	28.000	11.108	2.24	15.43	2.70	24.27
10.000	3.967	12.58	86.77	7.57	67.94	29.000	11.504	2.16	14.88	2.62	23.53
11.000	4.364	9.93	68.46	6.77	60.78	30.000	11.901	2.08	14.37	2.55	22.85
12.000	4.760	8.11	55.95	6.14	55.09	31.000	12.298	2.01	13.89	2.47	22.20
13.000	5.157	6.83	47.07	5.62	50.46	32.000	12.694	1.95	13.44	2.41	21.60
14.000	5.554	5.88	40.55	5.20	46.63	33.000	13.091	1.89	13.01	2.34	21.02
15.000	5.950	5.17	35.63	4.84	43.41	34.000	13.488	1.83	12.61	2.28	20.48
16.000	6.347	4.61	31.82	4.53	40.67	35.000	13.884	1.77	12.22	2.22	19.96
17.000	6.744	4.18	28.81	4.27	38.30	36.000	14.281	1.72	11.84	2.17	19.47
18.000	7.141	3.83	26.38	4.04	36.24	37.000	14.678	1.66	11.48	2.12	19.00
19.000	7.537	3.54	24.40	3.84	34.42	38.000	15.075	1.61	11.13	2.07	18.55
20.000	7.934	3.30	22.74	3.66	32.80	39.000	15.471	1.56	10.7?	2.02	18.12
21.000	8.331	3.10	21.34	3.49	31.36	40.000	15.868	1.52	10.45	1.97	17.70

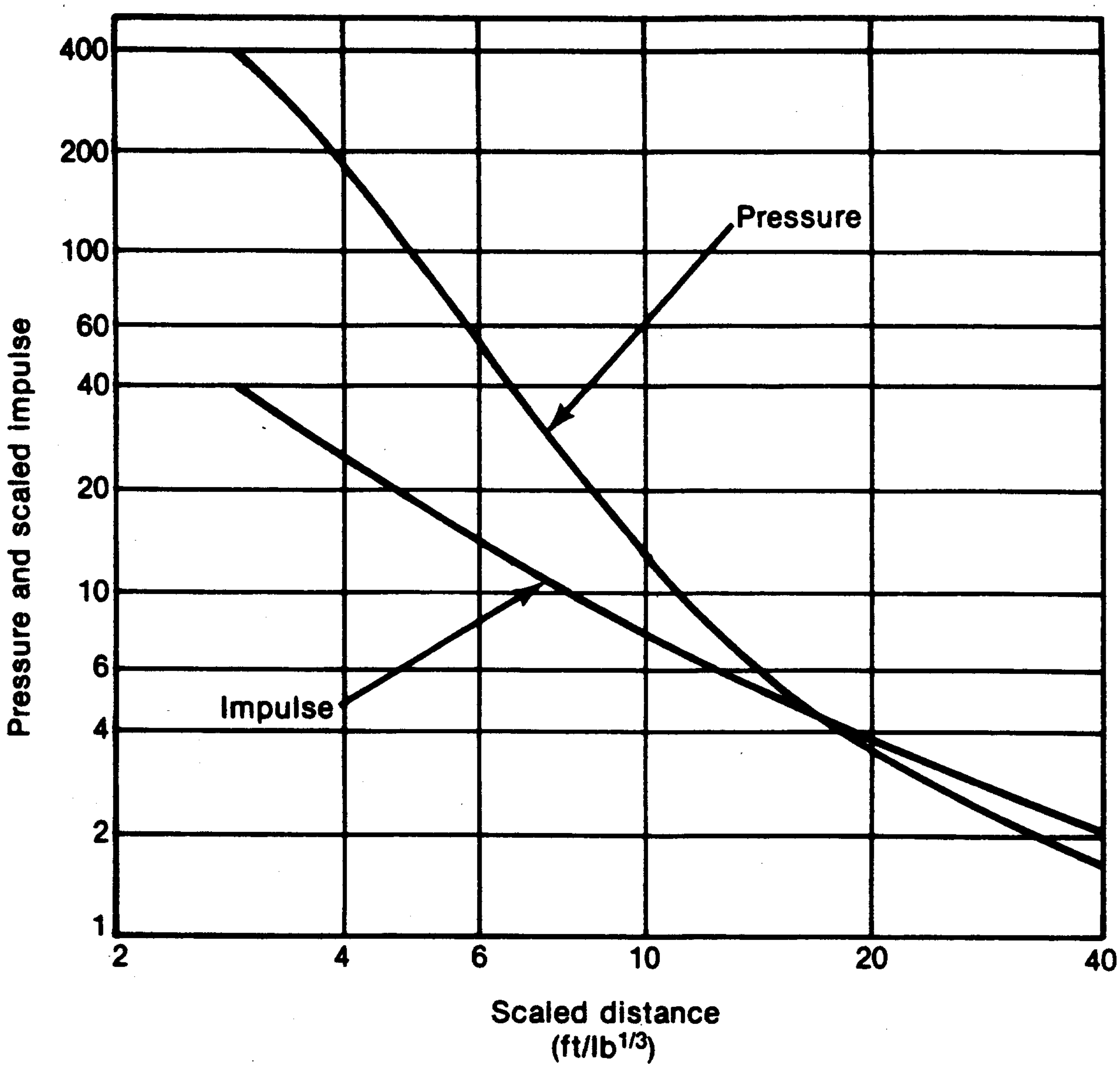


Figure 57. Pressure and Impulse Versus Scaled Distance for Cyclotol 70/30 in Orthorhombic Containers, L/D = 0.64:1.

Table 10. Summary of Results of Hemispherical Surface Bursts. Peak Pressure, and Scaled Positive Impulse Values for Cyclotol 70/30 in In-process Hoppers, L/D = 1.97:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	538.95	3716.04	37.72	338.53	22.000	8.727	3.63	25.03	2.32	20.63
4.000	1.587	369.90	2550.47	33.71	302.50	23.000	9.124	3.47	23.93	2.23	20.00
5.000	1.983	183.15	1262.82	26.30	236.00	24.000	9.521	3.32	22.89	2.16	19.35
6.000	2.380	91.76	632.72	19.96	179.11	25.000	9.917	3.18	21.90	2.10	18.81
7.000	2.777	50.38	347.37	15.27	137.03	26.000	10.314	3.04	20.93	2.05	18.38
8.000	3.174	30.60	210.97	11.92	106.96	27.000	10.711	2.90	19.97	2.01	18.04
9.000	3.570	20.35	140.33	9.52	85.45	28.000	11.108	2.76	19.02	1.98	17.77
10.000	3.967	14.61	100.77	7.78	69.85	29.000	11.504	2.62	18.06	1.96	17.57
11.000	4.364	11.17	77.04	6.50	58.35	30.000	11.901	2.48	17.11	1.94	17.44
12.000	4.760	8.99	61.96	5.54	49.72	31.000	12.298	2.34	16.15	1.93	17.35
13.000	5.157	7.53	51.90	4.80	43.12	32.000	12.694	2.20	15.20	1.93	17.33
14.000	5.554	6.51	44.91	4.23	38.00	33.000	13.091	2.07	14.25	1.93	17.34
15.000	5.950	5.78	39.87	3.78	33.97	34.000	13.488	1.90	13.31	1.94	17.40
16.000	6.347	5.24	36.12	3.43	30.75	35.000	13.884	1.80	12.39	1.95	17.51
17.000	6.744	4.82	33.24	3.14	28.17	36.000	14.281	1.67	11.49	1.97	17.65
18.000	7.141	4.49	30.97	2.90	26.07	37.000	14.678	1.54	10.61	1.99	17.86
19.000	7.537	4.27	29.46	2.75	24.66	38.000	15.075	1.42	9.76	2.01	18.04
20.000	7.934	4.00	27.57	2.56	22.93	39.000	15.471	1.30	8.94	2.04	18.28
21.000	8.331	3.80	26.22	2.43	21.77	40.000	15.868	1.18	8.16	2.07	18.56

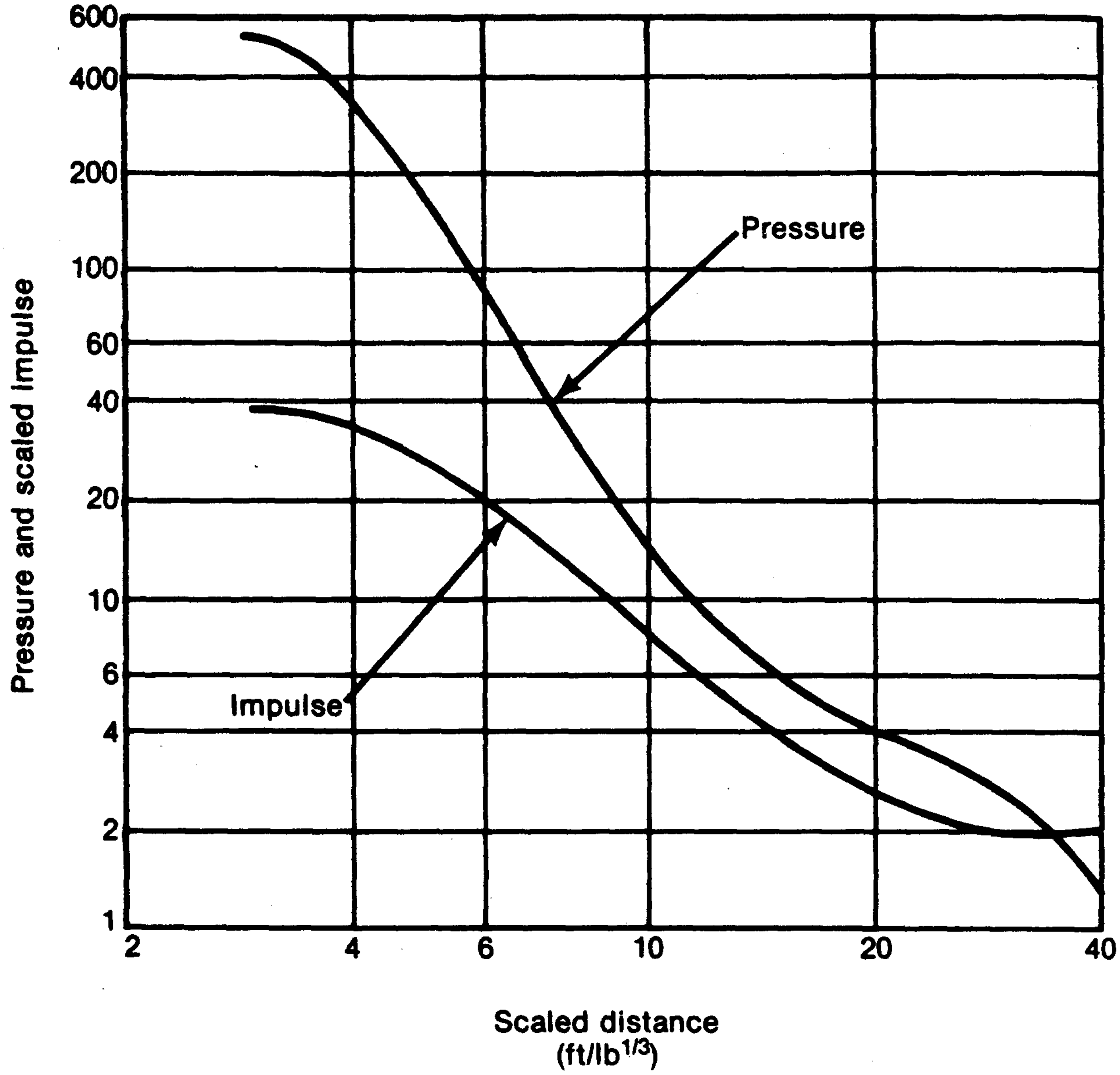


Figure 58. Pressure and Impulse Versus Scaled Distance for Cyclotol 70/30 in In-process Hoppers, L/D = 1.97:1.

EAK EXPLOSIVE[44]

OBJECTIVE

The objective of this test program was to determine the maximum output from the detonation of EAK explosives in terms of the peak overpressure and positive impulse. The measured values of peak pressure and scaled positive impulse data were compared to known characteristics of hemispherical TNT surface bursts to determine TNT equivalency.

MATERIAL

The EAK intermolecular explosives is not a standard military explosive. The formulation has been designated as an insensitive high explosive by the Air Force. It is presently a proposed filler for the standard MK82, GP (500 lb) bomb, and a modified formulation is proposed for large caliber projectile fills. The EAK was received from the Naval Weapons Station, Yorktown, Virginia, in metal shipping drums. Each drum contained 90.7 kg (200 lb) of EAK. The physical characteristics were chips of various thickness and dimensions.

TEST SETUP

EAK output was evaluated for weights and configurations simulating its shipping/storage container. The proposed shipping/storage was a fiber drum 43.18 cm diameter by 25.4 cm high (17 by 10 inches).

(1) A cylindrical container with a charge weight of 11.34 kg (25 lb) was used to simulate the shipping/storage container with dimensional scaling factor of 0.79. The L/D ratio was 0.59:1.

(2) A fiberboard cylindrical container with a charge weight of 22.68 kg (50 lb) was used to simulate the shipping/storage container with dimensional scaling factor of 1.0. The L/D ratio was 0.59:1.

INSTRUMENTATION

Twelve side-on pressure transducers were mounted flush to the ground surface in sand-filled 90-degree array. The scaled distances for the corresponding transducers ranged form 1.19 to 15.87 m/kg$^{1/3}$ (3.0 to 40.0 ft/lb$^{1/3}$) and were held constant throughout the experiments.

RESULTS

Results of the 11.34 kg cylindrical tests are given in Table 11 and Figure 59. Results of the 22.68 kg (50 lb) tests are given in Table 12 and Figure 60.

DISCUSSION

Peak pressure values for the 11.34 kg (25 lb) cylindrical tests varied as a function of the scaled diatance. The pressure values were eqiual to or greater than expected at scaled distances of 1.19, 3.57, and 7.14 $m/kg^{1/3}$ (3.0, 9.0, and 18.0 $ft/lb^{1/3}$) and less than expected at scaled distances of 1.59, 2.14, and 15.87 $m/kg^{1/3}$ (4.0, 5.4, and 40.0 $ft/lb^{1/3}$). The pressure values were 1072, 475, 222, 89, 27.7, and 7.8 kPa (155.47, 68,92, 32.15, 12.85 4.02, and 1.13 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 1.1, 0.8, 0.7, 1.0 1.2, and 0.7 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were less than expected at all scaled distances of the experiments. The scaled positive impulse values were 156, 114, 86, 48.5, 32.8, and 14.6 kPa-$ms/kg^{1/3}$ (17.35, 12.7, 9.55, 5.40, 3.65, and 1.63 psi-$ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 0.8, 0.7, 0.6, 0.5 0.8, and 0.7 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the 22.68 kg (50 lb) tests were equal to or greater than expected at scaled distances of 1.19, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$) and less than expected at scaled distances of 1.59 and 2.14 $m/kg^{1/3}$ (4.0 and 5.4 $ft/lb^{1/3}$). The pressure values were 1012, 517, 245, 106, 27.7, and 8.8 kPa (146.81, 75.02, 35.58, 15.33, 4.02, and 1.28 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 1.0, 0.9, 0.8, 1.3, 1.2, and 1.0 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were less than expected at all scaled distances of the experiment. The scaled positive impulse values were 177, 103, 89, 57.3, 28.5, and 16.1 kPa-$ms/kg^{1/3}$ (19.75, 11.47, 9.95, 6.39, 3.18, and 1.79 psi-$ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/lg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 1.0, 0.6, 0.7, 0.7, 0.7, and 0.8 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) The blast output from EAK is dependent upon the configuration from which it detonates.

(2) TNT equivalency values were determined for EAK in configurations that simulate the cylindrical shipping container.

(3) To within experimental limits, blast pressure and impulse scale as a cube root function of the charge weight.

(4) The pressure euivalency of EAK explosive as determined in this test series ranged from a high of 130% to as low as 70%. The impulse equivalencies were less than 100% at all scaled distances.

Table 11. Summary of Results for Hemispherical Surface Bursts, Peak Pressure and Scaled Positive Impusle Values for EAK Explosives 11.34 kg in Cylindrical Containers, L/D = 0.59:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	144.66	997.46	16.29	146.15	22.000	8.727	2.60	17.93	2.77	24.85
4.000	1.587	71.69	494.28	12.61	113.16	23.000	9.124	2.43	16.77	2.66	23.88
5.000	1.983	42.78	294.95	10.34	92.79	24.000	9.521	2.28	15.74	2.56	23.00
6.000	2.380	28.58	197.03	8.79	78.90	25.000	9.917	2.15	14.82	2.47	22.18
7.000	2.777	20.58	141.90	7.67	68.80	26.000	10.314	2.03	14.00	2.39	21.42
8.000	3.174	15.64	107.81	6.81	61.09	27.000	10.711	1.92	13.27	2.31	20.71
9.000	3.570	12.36	85.23	6.13	55.02	28.000	11.108	1.83	12.60	2.23	20.05
10.000	3.967	10.08	69.47	5.58	50.10	29.000	11.504	1.74	12.00	2.17	19.44
11.000	4.364	8.41	58.02	5.13	46.02	30.000	11.901	1.66	11.45	2.10	18.86
12.000	4.760	7.17	49.42	4.75	42.60	31.000	12.298	1.59	10.96	2.04	18.32
13.000	5.157	6.20	42.77	4.42	39.67	32.000	12.694	1.52	10.50	1.98	17.81
14.000	5.554	5.44	37.53	4.14	37.14	33.000	13.091	1.46	10.08	1.93	17.33
15.000	5.950	4.83	33.31	3.89	34.93	34.000	13.488	1.41	9.69	1.88	16.87
16.000	6.347	4.33	29.86	3.68	32.98	35.000	13.884	1.35	9.33	1.83	16.44
17.000	6.744	3.91	26.99	3.48	31.25	36.000	14.281	1.31	9.00	1.79	16.04
18.000	7.141	3.56	24.58	3.31	29.70	37.000	14.678	1.26	8.69	1.74	15.65
19.000	7.537	3.27	22.53	3.15	28.31	38.000	15.075	1.22	8.41	1.70	15.28
20.000	7.934	3.01	20.78	3.01	27.05	39.000	15.471	1.18	8.14	1.66	14.93
21.000	8.331	2.79	12.96	2.89	25.90	40.000	15.868	1.14	7.89	1.63	14.60

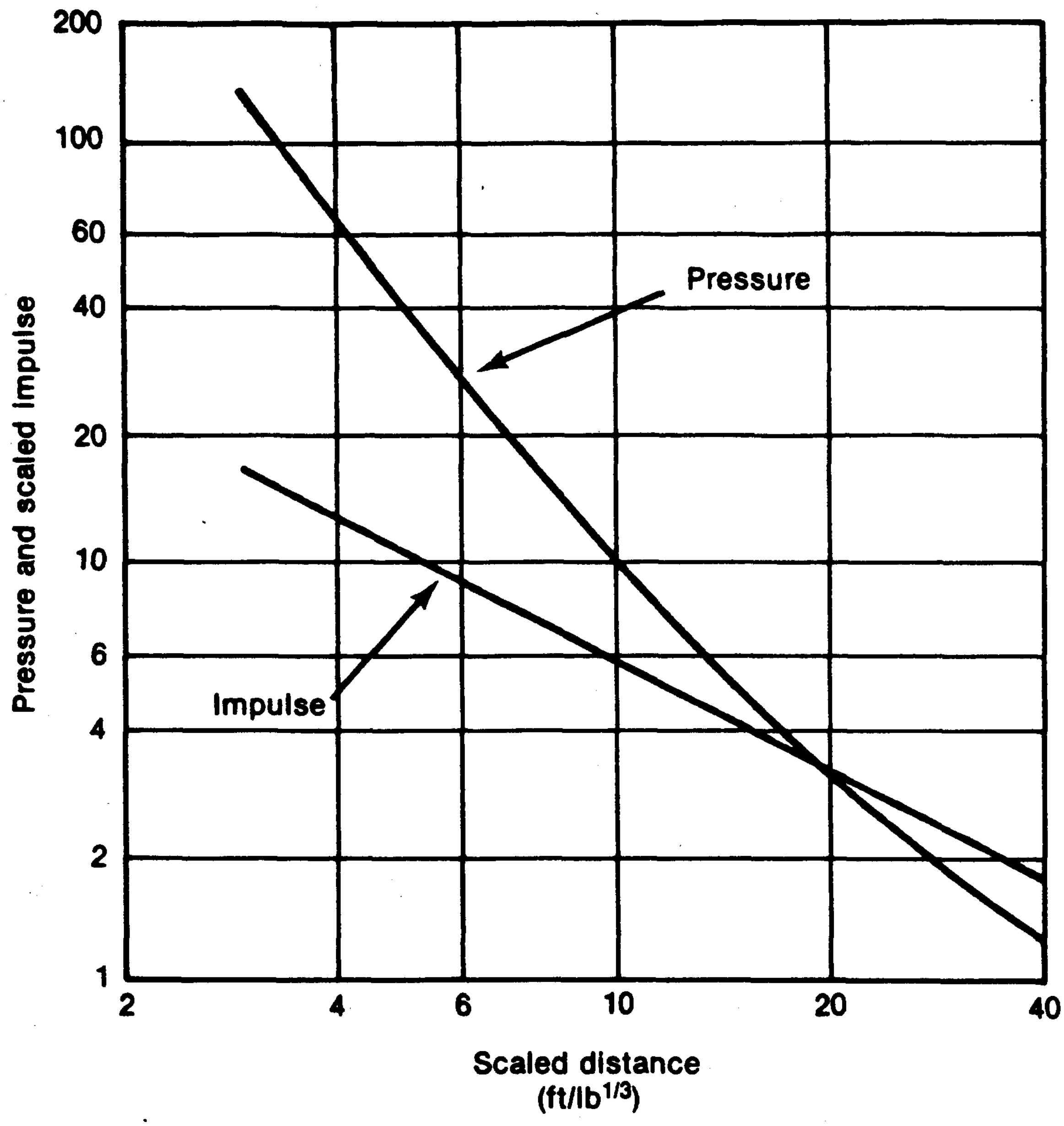


Figure 59. Pressure and Scaled Positive Impulse Versus Scaled Distance for EAK Explosives in Cylindrical Containers, L/D = 0.59:1.

Table 12. Summary of Results for Hemispherical Surface Bursts, Peak Pressure and Scaled Positive Impulse for EAK Explosive in Clyindrical Containers, 22.7 kg, L/D = 0.59:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	144.72	997.83	16.18	145.23	22.000	8.727	2.94	20.25	2.88	25.84
4.000	1.587	74.04	510.47	12.61	113.19	23.000	9.124	2.75	18.94	2.77	24.87
5.000	1.983	45.13	311.20	10.40	93.29	24.000	9.521	2.58	17.77	2.67	23.97
6.000	2.380	30.62	211.09	8.88	79.66	25.000	9.917	2.43	16.74	2.58	23.14
7.000	2.777	22.30	153.77	7.77	69.70	26.000	10.314	2.29	15.81	2.49	23.36
8.000	3.174	17.09	117.86	6.92	62.09	27.000	10.711	2.17	14.97	2.41	21.64
9.000	3.570	13.61	93.82	6.25	56.06	28.000	11.108	2.06	14.22	2.34	20.97
10.000	3.967	11.15	76.89	5.70	51.17	29.000	11.504	1.96	13.53	2.27	20.34
11.000	4.364	9.38	64.50	5.25	47.12	30.000	11.901	1.87	12.91	2.20	19.75
12.000	4.760	8.00	55.13	4.87	43.70	31.000	12.298	1.79	12.34	2.14	19.20
13.000	5.157	6.94	47.85	4.54	40.77	32.000	12.694	1.71	11.82	2.08	16.68
14.000	5.554	6.10	42.08	4.26	38.23	33.000	13.091	1.64	11.34	2.03	18.19
15.000	5.950	5.43	37.42	4.01	36.81	34.000	13.488	1.58	10.90	1.98	17.72
16.000	6.347	4.87	33.09	3.80	34.06	35.000	13.884	1.52	10.49	1.93	17.29
17.000	6.744	4.41	30.40	3.60	32.31	36.000	14.281	1.47	10.11	1.88	16.87
18.000	7.141	4.02	27.71	3.43	30.75	37.000	14.678	1.41	9.75	1.81	16.47
19.000	7.537	3.69	25.42	3.27	29.35	38.000	15.075	1.37	9.42	1.79	16.10
20.000	7.934	3.40	23.45	3.13	28.07	39.000	15.471	1.32	9.12	1.75	15.74
21.000	8.331	3.15	21.74	3.00	26.91	40.000	15.868	1.28	8.83	1.72	15.40

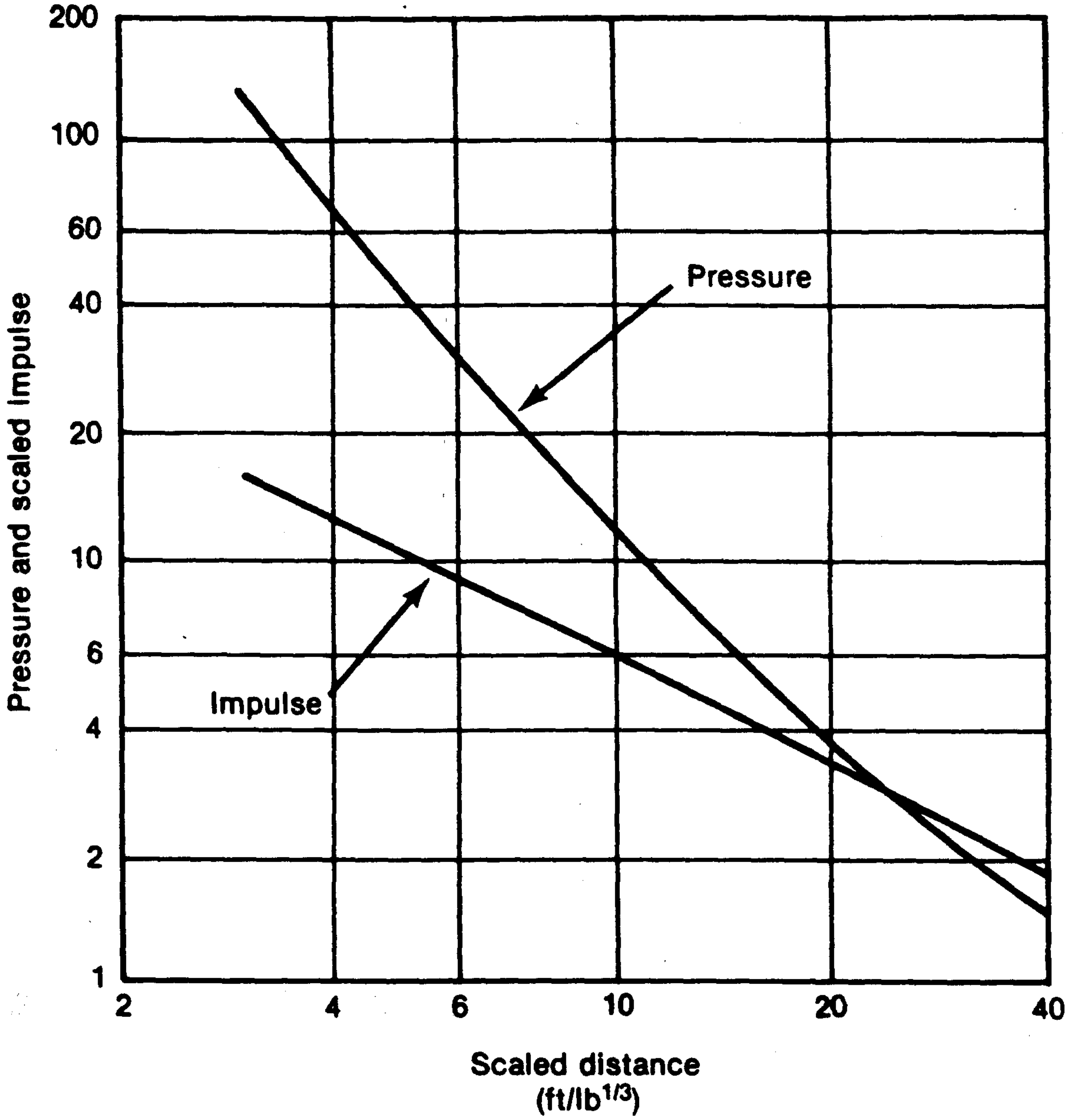


Figure 60. Pressure and Scaled Positive Impulse Versus Scaled Distance for EAK Explosive in Cylindrical Container, 22.68 kg, L/D = 0.59:1.

OBJECTIVE

The objective of this study was to measure the maximum pressure and positive impulse of Guanidine Nitrate in simulated storage bins and determine its TNT equivalency.

MATERIAL

Guanidine nitrate was received in bulk powder form and was tested in simulated storage bin configurations. Guanidine nitrate has a bulk density of 0.72 g/cm^3.

TEST SETUP

Airblast output was evaluated for weights of Guanidine Nitrate in bulk power form and was tested in weights of 66, 109, 218, and 363 kg (145, 240, 480 and 800 lb). The length to diameter ratio (L/D) for all tests were 1:1. Physical characteristics of the test items were:

(1) Plywood boxes were constructed from 6.35 mm (0.25 inch) thick and supported by 50.8 x 101.6 mm (2 x 4 inch) lumber to support the boxes. The boxes were used to shape the explosive but afforded minimal confinement. The explosive was loosely poured into the boxes. There was no attempt to compact the material.

Initiation was accomplished using a Composition C4 booster in the shape of a cube with a L/D ratio of 1:1 embedded near the top surface of the charge. Two US Army special blasting caps wired in parallel were used to ignite the booster.

INSTRUMENTATION

Pressure gages were flush mounted in 20 inch square by 1 inch thick steel plates which were, in turn, flush mounted to the ground stakes. They were located at discrete intervals on a radial line from ground zero. The gage positions ranged from 20 to 330 ft from ground zero. Nine gages were positioned in the field to provide greater pressure range flexibility from test to test though only six were used during any one test.

RESULTS

Table 13 shows the combined results of all of the charge weights. Figure 61 represents a plot of the data for both pressure and scaled positive impulse. All of the data was in good agreement for the charge sizes tested. However, the 66 kg (145 lb) charge weight values were lower than the other charge weights. Still the data from these tests were within one standrard deviation of the other charge weights and are combined with all of the charge weights for the reporting purposes.

DISCUSSION

The combined results of all charge weights were generally equal to or less than the expected values at all scaled distances of the experiment. The pressure values were 941, 460, 223, 70, 16, and 3.4 kPa (136.5, 66.7, 32.4, 1.,1, 2.3, and 0.5 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14 and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 1.0, 1.0, 1.0, 0.8, 0.5, and 0.2 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were 173, 127, 91, 52, 24, and 9.9 $kPa\text{-}ms/kg^{1/3}$ (19.3, 14.1, 10.1, 5.8, 2.7, and 1.1 $psi\text{-}ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These values equate to 1.0, 0.9, 0.8, 0.6, 0.4, and 0.4 times equal amounts of TNT at the same scaled distances. respectively.

CONCLUSIONS

(1) TNT is more difficult to shock initiate than guanidine nitrate.

(2) When initiated, guanidine nitrate has a low rate of detonation.

(3) Guanidine nitrate pressure values were equal to those of equal amounts of TNT at scaled distances of 1.19, 1.59, and 2.14 $m/kg^{1/3}$ (3.0, 4.0, and 5.4 $ft/lb^{1/3}$). Pressure values were less than equal amounts of TNT at all scaled distances equal to or greater than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$).

(4) To within experimental limits, blast pressure and impulse scale as a cube root function of the charge weights.

Table 13. Summary of Results of Hemispherical Surface Bursts, Peak Pressure and Scaled Positive Impulse Values for. Guanidine Nitrate in Orthorhombic Configuration, L/D = 1:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	136.46	940.89	19.33	173.46	22.000	8.727	1.56	10.75	2.17	19.37
4.000	1.587	66.72	460.02	14.08	126.40	23.000	9.124	1.43	9.85	2.06	18.45
5.000	1.983	38.93	268.40	11.02	98.88	24.000	9.521	1.32	9.07	1.96	17.60
6.000	2.380	25.33	174.65	9.02	80.91	25.000	9.917	1.22	8.39	1.88	16.83
7.000	2.777	17.44	122.35	7.61	68.29	26.000	10.314	1.13	7.78	1.80	16.12
8.000	3.174	13.11	90.38	6.57	58.96	27.000	10.711	1.05	7.24	1.72	15.46
9.000	3.570	10.08	69.49	5.77	51.79	28.000	11.108	0.98	6.76	1.66	14.86
10.000	3.967	7.99	55.11	5.14	46.12	29.000	11.504	0.92	6.32	1.59	14.29
11.000	4.364	6.50	44.81	4.63	41.53	30.000	11.901	0.86	5.93	1.53	13.77
12.000	4.760	5.39	37.17	4.21	37.74	31.000	12.298	0.81	5.58	1.48	13.28
13.000	5.157	4.55	31.37	3.85	34.56	32.000	12.694	0.76	5.26	1.43	12.83
14.000	5.554	3.89	26.85	3.55	31.85	33.000	13.091	0.72	4.97	1.38	12.40
15.000	5.950	3.37	23.26	3.29	29.52	34.000	13.488	0.68	4.70	1.34	12.05
16.000	6.347	2.95	20.36	3.06	27.50	35.000	13.884	0.65	4.46	1.30	11.62
17.000	6.744	2.61	17.99	2.87	25.72	36.000	14.281	0.61	4.24	1.26	11.27
18.000	7.141	2.32	16.02	2.69	24.16	37.000	14.678	0.58	4.03	1.22	10.93
19.000	7.537	2.08	14.37	2.54	22.76	38.000	15.075	0.56	3.84	1.18	10.67
20.000	7.934	1.88	12.97	2.40	21.51	39.000	15.471	0.53	3.67	1.15	10.32
21.000	8.331	1.71	11.78	2.27	20.39	40.000	15.868	0.51	3.50	1.12	10.03

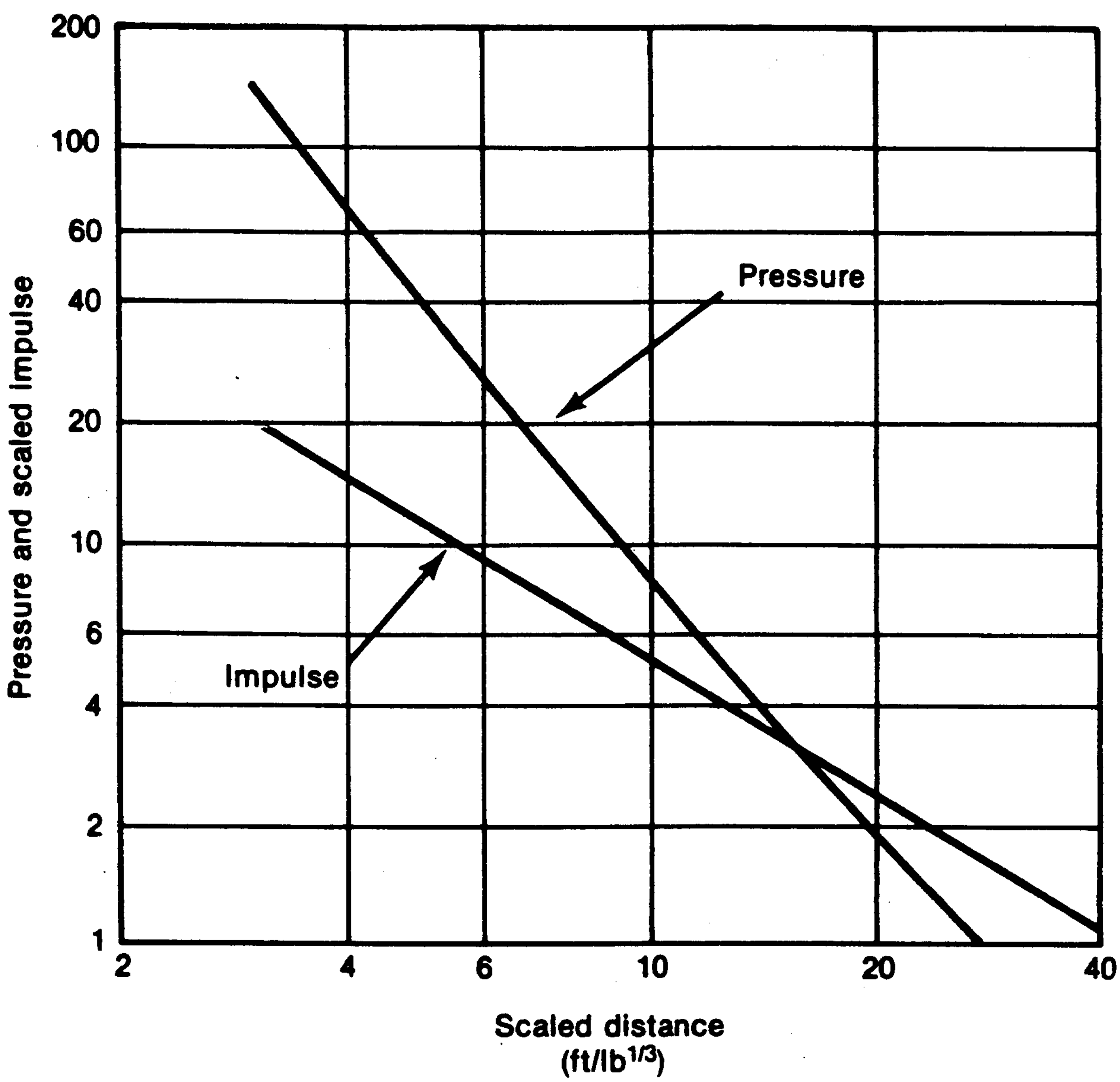


Figure 61. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for Guanidine Nitrate, L/D = 1:1.

OBJECTIVE

The objective of this study was to determine the maximum output from the detonation of HMX high explosive in configurations which are encountered in specific locations in the manufacturing facilities. The measured pressure and impulse data were compared with known TNT test data to determine the TNT equivalency of HMX.

MATERIAL

HMX is a solid high explosive commonly used as a booster and a main charge. It is a white substance with a melting point of 276 °C and a density of 1.87 g/cm^3. HMX is usually pressed into its containers. HMX was received and tested wetted with isopropyl alcohol.

TEST SETUP

HMX explosive was evaluated for weights and configurations simulating a transfer container and a cylindrical shipping container. Physical characteristics of the test items are as follows:

(1) A fiberboard cylindrical container with charge weights of 22.7 and 45.5 kg (50 and 100 lb) with a L/D ratio of 0.8:1

(2) A plywood orthorhombic container with a charge weight of 27.2 and 54.4 kg (60 and 120 lb) with a L/D ratio of 0.5:1.

Each test charge was initiated with a J2 engineers' special blasting cap and a conical-shaped booster charge of Composition C4.

INSTRUMENTATION

Twelve piezoelectric side-on pressure transducers were mounted flush to the surface in a 90-degree array. Scaled distances from 1.19 to 15.87 m/kg$^{1/3}$ (3.0 to 40.0 ft/lb$^{1/3}$) were held constant throughout the experiments.

RESULTS

Pressure and impulse values for the combined charge weights of the cylindrical tests are given in Table 14 and Figure 62. Pressure and impulse values for the combined results of the orhtorhombic test configuration are given in Table 15 and Figure 63. All reported values are within one standard deviation of the mean.

DISCUSSION

Peak pressure values for the cylindrical test configuration were greater than expected at all scaled distances of the experiment. The pressure values were 2081, 1094, 458, 91, 26, and 8.5 kPa (301.8, 158.6, 66.4, 13.2, 3.7, and 1.24 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40

$ft/lb^{1/3}$), respectively. These values equate to 3.0, 3.5, 1.7, 1.2, 1.1, and 1.1 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were less than expected at all scaled distances of the experiments. Scaled positive impulse values were 159, 127, 94, 57, 30, and 10.8 kPa-ms/$kg^{1/3}$ (17.7, 14.2, 10.5, 6.3, 3.3, and 1.2 psi-ms/$lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/$kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/$lb^{1/3}$), respectively. These scaled positive impulse values equate to 0.9, 0.9, 0.8, 0.7, 0.7, and 0.5 times equal amounts of TNT at the same scaled distances, respectively.

Pressure values for the combined results of the orthorhombic test configuration were greater than expected at scaled distances equal to or less than 3.57 m/$kg^{1/3}$ (9.0 ft/$lb^{1/3}$) and less than expected at scaled distances equal to or greater than 7.14 m/$kg^{1/3}$ (18.0 ft/$lb^{1/3}$). Pressure values were 2233, 1334, 562, 107, 19, and 7.4 kPa (323.9, 193.5, 81.5, 15.5, 2.8, and 1.07 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/$kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/$lb^{1/3}$), respectively. These pressure values equate to 3.4, 4.0, 3.1, 1.5, 0.6, and 0.8 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were less than expected at a scaled distance of 1.19 m/$kg^{1/3}$ (3.0 ft/$lb^{1/3}$) greater than expected at scaled distances of 1.59 and 2.14 m/$kg^{1/3}$ (4.0 and 5.4 ft/$lb^{1/3}$) and less than expected at all other scaled distances of the experiments. Scaled positive impulse values were 155, 163, 121, 53, 20, and 7.2 kpa-ms/$kg^{1/3}$ (17.3, 18.2, 13.5, 5.9, 2.2, and 0.8 psi-ms/$lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/$kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/$lb^{1/3}$), respectively. These scaled positive impulse values equate to 0.9, 1.0, 1.8, 0.6, 0.4, and 0.2 times equal amounts of TNT at the same scaled distances, respectively.

The variances in the pressure and impulse values were attributed to the test geometries.

CONCLUSIONS

(1) Pressure and impulse values for HMX are dependent upon the charge shape (geometry).

(2) Pressure values for HMX in the clyindrical configuration with a L/D ratio of 0.8:1 were greater than expected at all scaled distances of the experiment.

(3) Impulse values for HMX in cylindrical configurations with a L/D ratio of 0.8:1 were generally equal to or less than expected for all scaled distances.

(4) Peak pressure values for HMX in orthorhombic configurations were greater than expected at scaled distances equal to or less than 3.57 m/$kg^{1/3}$ (9.0 ft/$lb^{1/3}$) and equal to or less than expected at scaled distances greater than 7.14 m/$kg^{1/3}$ (18.0 ft/$lb^{1/3}$).

(5) Scaled positive impulse values for HMX in orthorhombic configurations were less than expected at all scaled distances with the exception at scaled distances of 1.59 and 2.14 $m/kg^{1/3}$ (4.0 and 5.4 $ft/lb^{1/3}$) where the impulse values were greater than expected.

(6) To within experimental limits, blast overpressure and impulse scale as a cube root function of the charge weight.

Table 14. Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse Values for HMX in Cylindrical Containers, L/D = 0.8:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	301.83	2081.14	17.51	157.11	22.000	8.727	3.05	21.01	2.50	22.42
4.000	1.587	158.63	1093.72	13.76	123.46	23.000	9.124	2.92	20.11	2.37	21.31
5.000	1.983	80.14	552.59	11.31	101.45	24.000	9.521	2.79	19.27	2.26	20.29
6.000	2.380	44.27	305.22	9.57	85.90	25.000	9.917	2.68	18.48	2.16	19.36
7.000	2.777	27.11	186.89	8.28	74.31	26.000	10.314	2.57	17.72	2.06	18.49
8.000	3.174	18.18	125.38	7.28	65.34	27.000	10.711	2.46	16.99	1.97	17.69
9.000	3.570	13.15	90.68	6.48	58.19	28.000	11.108	2.36	16.27	1.89	16.95
10.000	3.967	10.11	69.68	5.83	52.36	29.000	11.504	2.26	15.57	1.81	16.26
11.000	4.364	8.15	56.19	5.29	47.51	30.000	11.901	2.16	14.88	1.74	15.62
12.000	4.760	6.83	47.09	4.84	43.42	31.000	12.298	2.06	14.20	1.67	15.02
13.000	5.157	5.90	40.68	4.45	39.93	32.000	12.694	1.96	13.53	1.61	14.46
14.000	5.554	5.22	36.01	4.11	36.91	33.000	13.091	1.87	12.86	1.55	13.94
15.000	5.950	4.71	32.49	3.82	34.28	34.000	13.488	1.77	12.21	1.50	13.44
16.000	6.347	4.32	29.77	3.56	31.97	35.000	13.884	1.68	11.57	1.45	12.98
17.000	6.744	4.00	27.60	3.33	29.92	36.000	14.281	1.59	10.93	1.40	12.54
18.000	7.141	3.75	25.84	3.13	28.09	37.000	14.678	1.50	10.31	1.35	12.13
19.000	7.537	3.53	24.36	2.95	26.46	38.000	15.075	1.41	9.71	1.31	11.74
20.000	7.934	3.35	23.10	2.78	24.98	39.000	15.471	1.32	9.12	1.27	11.37
21.000	8.331	3.19	22.00	2.63	23.64	40.000	15.868	1.24	8.54	1.23	11.02

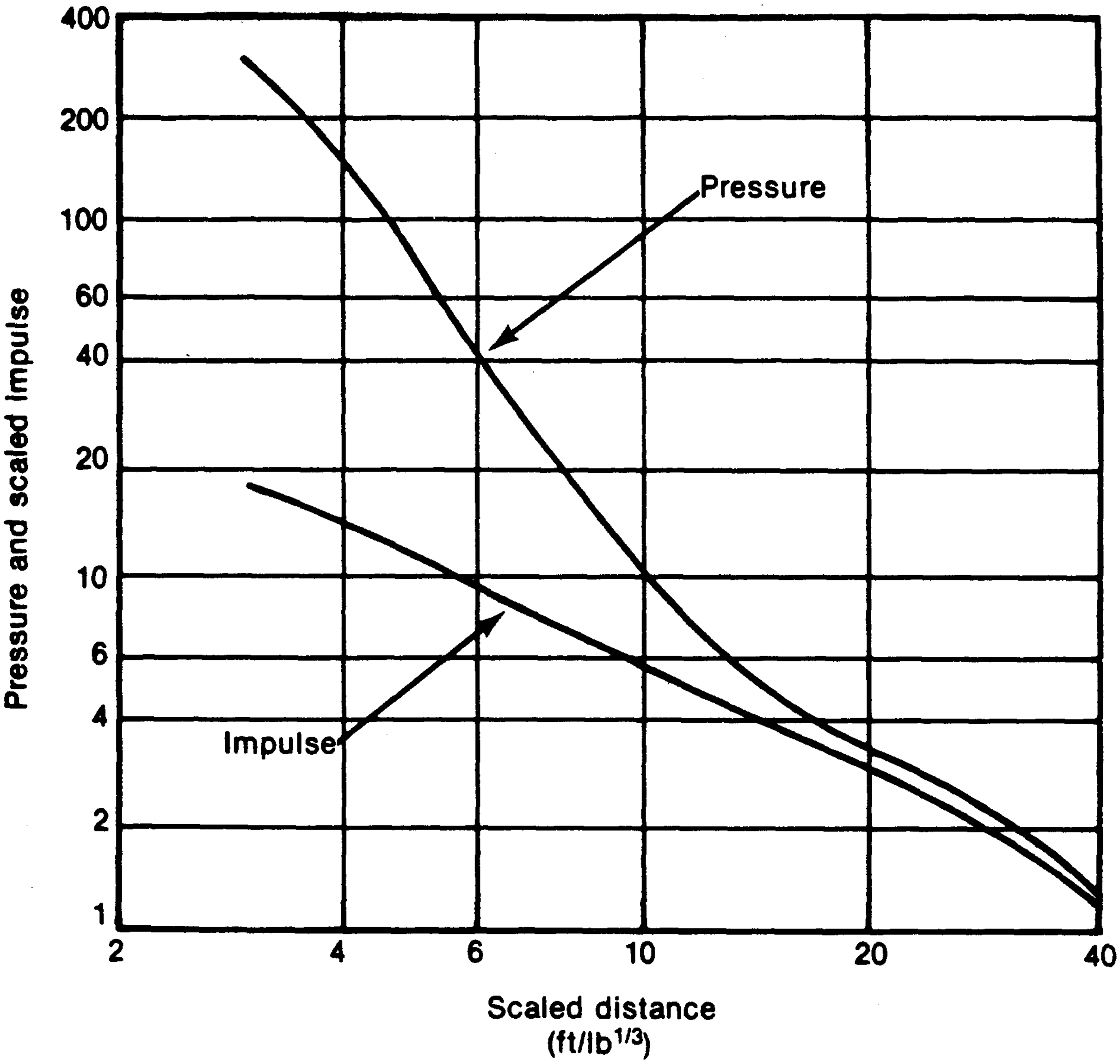


Figure 62. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for HMX in Cylindrical Containers, L/D = 0.8:1.

Table 15. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Impulse Values for HMX in Orthorhombic Containers, L/D = 0.5:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	323.53	2230.73	20.84	186.98	22.000	8.727	2.07	14.27	1.88	16.86
4.000	1.587	194.66	1342.19	15.73	141.19	23.000	9.124	1.95	13.44	1.76	15.78
5.000	1.983	104.81	722.69	12.46	111.81	24.000	9.521	1.85	12.73	1.65	14.81
6.000	2.380	58.68	404.57	10.19	91.48	25.000	9.917	1.76	12.12	1.55	13.92
7.000	2.777	35.27	243.16	8.54	76.66	26.000	10.314	1.68	11.57	1.46	13.12
8.000	3.174	22.77	157.01	7.29	65.44	27.000	10.711	1.61	11.09	1.38	12.38
9.000	3.570	15.67	108.06	6.32	56.68	28.000	11.108	1.55	10.66	1.30	11.71
10.000	3.967	11.39	78.54	5.54	49.69	29.000	11.504	1.49	10.27	1.24	11.09
11.000	4.344	8.67	59.76	4.90	43.99	30.000	11.901	1.44	9.92	1.17	10.52
12.000	4.760	6.85	47.26	4.38	39.28	31.000	12.298	1.39	9.59	1.11	9.99
13.000	5.157	5.60	38.60	3.94	35.33	32.000	12.694	1.35	9.29	1.06	9.50
14.000	5.554	4.70	32.39	3.56	31.98	33.000	13.091	1.31	9.01	1.01	9.05
15.000	5.950	4.03	27.80	3.24	29.10	34.000	13.488	1.27	8.74	0.96	8.63
16.000	6.347	3.53	24.32	2.97	26.62	35.000	13.884	1.23	8.49	0.92	8.24
17.000	6.744	3.14	21.63	2.72	24.45	36.000	14.281	1.20	8.29	0.89	7.95
18.000	7.141	2.83	19.50	2.51	22.55	37.000	14.678	1.16	8.02	0.84	7.54
19.000	7.537	2.58	17.80	2.33	20.87	38.000	15.075	1.13	7.79	0.80	7.22
20.000	7.934	2.38	16.40	2.16	19.38	39.000	15.471	1.10	7.58	0.77	6.92
21.000	8.331	2.21	15.24	2.01	18.05	40.000	15.868	1.07	7.37	0.74	6.64

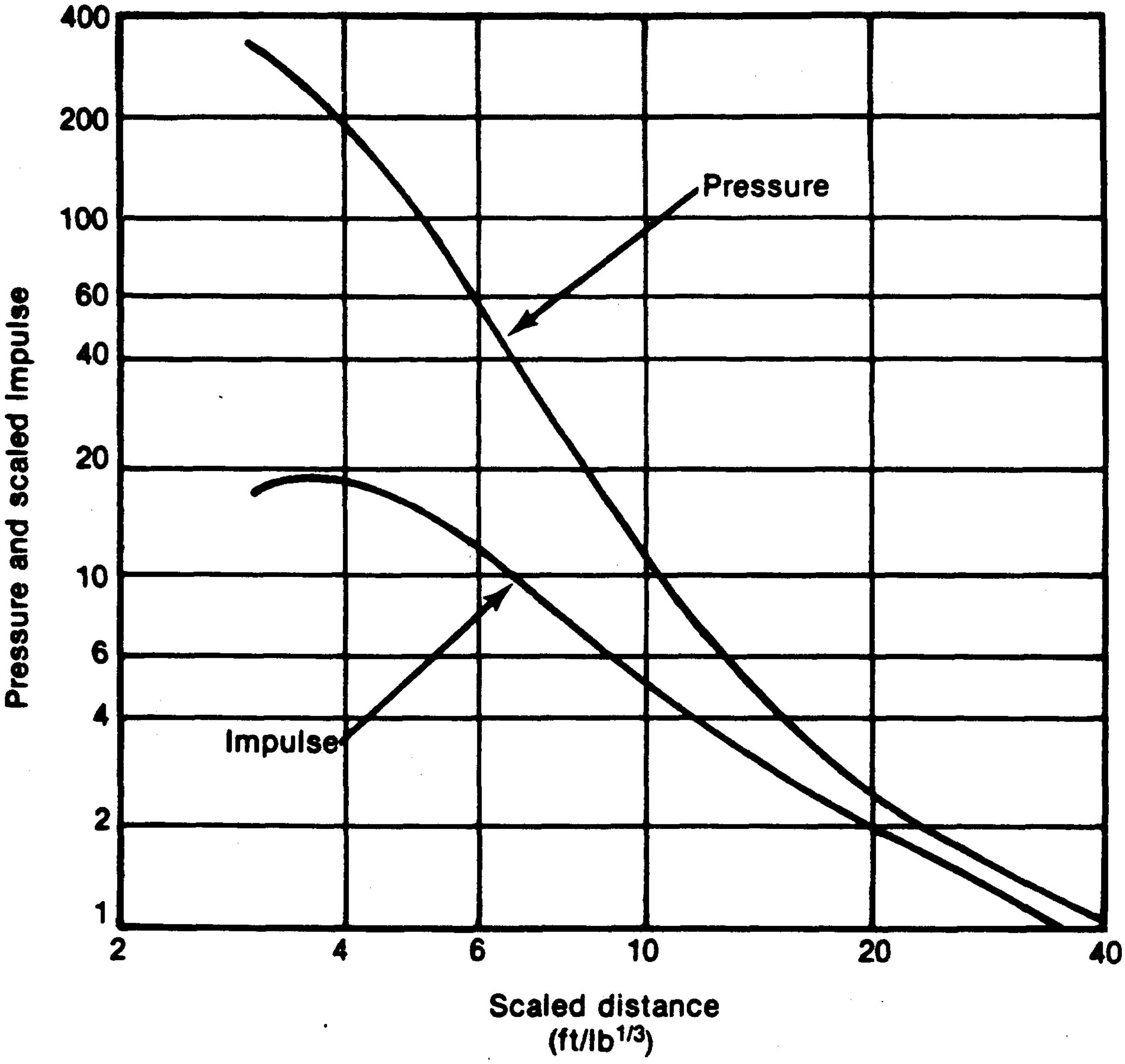


Figure 63. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for HMX in Orthorhombic Containers, L/D = 0.5:1.

LX-14[11]

OBJECTIVE

The objective of this study was to determine the maximum blast pressure output from the detonation of HMX explosives in various in-plant configurations. The measured pressure and impulse values were compared with known characteristics of hemispherical TNT data to determine the TNT equivalency of LX-14 high explosive.

MATERIAL

LX-14-0 Blend 2 is a high explosive molding powder with a nominal composition of 95.5% HMX and 4.5% estane. LX-14 was received in bulk powder form and pressed cylindrical billets.

TEST SETUP

Airblast parameters were evaluated for charge weight of 0.45, 13.6, 27.2, 54.4, 68.0 and 72.6 kg (1.0, 30.0, 60.0, 120.0, 150.0 and 160.0 lb) in in-process configurations and pressed billets. The physical characteristics of the test items are as follows:

(1) An aluminum orthorhombic container representing scaling factors of 0.36, 0.45 and 0.57 for charge weights of 13.6, 27.2 and 54.4 kg (30, 60 and 120 lb) with a height to length ratio of 0.36:1 were used for all bulk tests.

(2) An orthorhombic aluminum transfer cart was used to conduct 68.0 and 72.6kg (150 and 160 lb) bulk and pressed billets tests. The effective height to length ratio was 0.4:1.

(3) Pressed 0.4 kg (1.0 lb) billets with a length to diameter ratio of 2:1 were tested placed on a witness plate on the ground surface.

A 1010 cold-rolled carbon steel witness plate was used to determine if a detonation occurred. A conicall-shaped booster charge consisting of Composition C4 was used along with a J2 engineers' special blasting cap as the initiation source for all tests.

INSTRUMENTATION

Twelve piezoelectric side-on pressure transducers were mounted flush to the ground in a 90-degree array. Scaled distances from 1.19 to 15.87 $m/kg^{1/3}$ (3.0 to 40.0 $ft/lb^{1/3}$) were held constant throughout all of the experiments.

RESULTS

All of the orthorhombic test configurations had similar L/D ratios and the pressure and impulse values were similar. As the result of the test series all of the orthorhombic test configurations were combined. The results of combined values are given in Table 16 and Figure 64. The pressed billets with a L/D ratio of 2:1 are given in Table 17 and Figure 65. Table 18 and Figure 66 show the results of the combined weights of the transporter tests.

DISCUSSION

All pressure values for the combined charge weights were greater than expected at all scaled distances equal to or greater than 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$) and less than expected at a scaled distance of 15.87 m/kg$^{1/3}$ (40.0 ft/lb$^{1/3}$). The pressure values were 2419, 1427, 554, 101, 30, and 6.9 kPa (350.9, 206.9, 80.4, 14.7 4.3, and 1.0 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40 ft/lb$^{1/3}$), respectively. These values equate to 3.9, 3.6, 3.2, 1.3, 1.1, and 0.7 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were greater than expected at all scaled distances with the exception noted at a scale distance of 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$) where the impulse value was less than expected. Scaled positive impulse values were 359, 239, 143, 66, 39, and 19.7 kPa-ms/kg$^{1/3}$ (40.0, 26.6, 15.9, 7.4, 4.3, and 2.2 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14 and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These values equate to 3.5, 3.6, 3.2, 0.9, 1.1, and 1.2 times equal amounts of TNT at the same scaled distances, respectively.

Pressue values for the orthorhombic configuration of the transfer carts were greater than expected at all scaled distances. The pressure values were 2305, 977, 396, 164, 44, and 12.1 kPa (334.3, 141.7, 57.5, 23.8, 6.4, and 1.75 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These values equate to 3.5, 2.6, 1.9, 2.6, 2.9, and 2.4 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were greater than expected at scaled distances equal to or less than 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$) and less than expected at scaled distances equal to or greater than 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$). The scaled positive impulse values were 253, 225, 159, 75, 28, and 12.5 kPa-ms/kg$^{1/3}$ (28.2, 25.1, 17.7, 8.4, 3.1, and 1.4 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These values equate to 1.9, 2.4, 2.0, 1.2, 0.7, and 0.6 times equal amounts of TNT at the same scaled distances, respectively.

Pressure values for the pressed billets with a L/D ratio of 2:1 were equal to or greater than expected at scaled distances equal to or less than 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$) and less than expected at a scaled distance of 15.87 m/kg$^{1/3}$ (40.0 ft/lb$^{1/3}$). The pressure values were 1926, 1023, 489, 143, 3.7, and 9.2 kPa (279.3, 148.3, 70.9, 20.7, 5.3, and 1.34 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.8 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 1.6, 1.2, 1.1, 1.1, 1.0, and 0.8 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were slightly greater than expected at a scaled distance of 1.19 m/kg$^{1/3}$ (3.0 ft/lb$^{1/3}$) and less than expected at all other scaled distances. The scaled positive impulse values were 114, 234, 242, 114, 35, and 12 kPa-ms/kg$^{1/3}$ (12.7, 26.1, 27.0, 12.7, 3.9, and 1.3 psi-ms/$lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/$kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/$lb^{1/3}$), respectively. These values equate to 1.1, 0.9, 0.8, 0.8, 0.8, and 0.8 times equal amounts of TNT at the same scaled distances, respectively.

The pressure and impulse values varied as a function of the test configurations.

CONCLUSIONS

(1) To within experimental limits, blast overpressure and impulse scale as a cube root function of the charge weight.

(2) Pressure and Impulse values for LX-14 were dependent upon the charge shape (geometry).

Table 16. Summary of Results of Hemispherical Surface Bursts, Peak Pressure and Impulse Values for LX-14 in Orthorhombic Container, L/D = 0.4:1

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse psi · ms/$lb^{1/3}$	Scaled Impulse kPa · ms/$kg^{1/3}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse psi · ms/$lb^{1/3}$	Scaled Impulse kPa · ms/$kg^{1/3}$
3.000	1.190	350.91	2419.50	38.57	346.11	22.000	8.727	2.86	19.70	3.40	30.55
4.000	1.587	206.93	1426.79	24.77	222.29	23.000	9.124	2.72	18.75	3.28	29.44
5.000	1.983	104.50	720.51	17.95	161.09	24.000	9.521	2.59	17.87	3.17	28.43
6.000	2.380	55.76	384.45	13.99	125.56	25.000	9.917	2.47	17.04	3.07	27.51
7.000	2.777	32.73	225.69	11.44	102.70	26.000	10.314	2.36	16.24	2.97	26.68
8.000	3.174	21.09	145.38	9.69	86.92	27.000	10.711	2.24	15.48	2.89	25.91
9.000	3.570	14.71	101.43	8.41	75.45	28.000	11.108	2.14	14.73	2.81	25.20
10.000	3.967	10.96	75.57	7.44	66.77	29.000	11.504	2.03	14.00	2.74	24.55
11.000	4.364	8.61	59.37	6.69	60.00	30.000	11.901	1.93	13.29	2.67	23.95
12.000	4.760	7.06	48.68	6.08	54.58	31.000	12.298	1.83	12.58	2.61	23.39
13.000	5.157	5.99	41.31	5.59	50.15	32.000	12.694	1.72	11.89	2.55	22.87
14.000	5.554	5.52	36.02	5.18	46.48	33.000	13.091	1.63	11.21	2.49	22.39
15.000	5.950	4.65	32.09	4.83	43.38	34.000	13.488	1.53	10.55	2.44	21.93
16.000	6.347	4.22	29.09	4.54	40.73	35.000	13.884	1.44	9.90	2.40	21.51
17.000	6.744	3.88	26.73	4.28	36.45	36.000	14.281	1.34	9.26	2.35	21.11
18.000	7.141	3.60	26.83	4.06	36.46	37.000	14.678	1.25	8.65	2.31	20.74
19.000	7.537	3.37	23.25	3.87	34.71	38.000	15.075	1.17	8.05	2.27	20.38
20.000	7.934	3.18	21.91	3.70	33.16	39.000	15.471	1.08	7.47	2.23	20.05
21.000	8.331	3.01	20.74	3.54	31.78	40.000	15.868	1.00	6.92	2.20	19.74

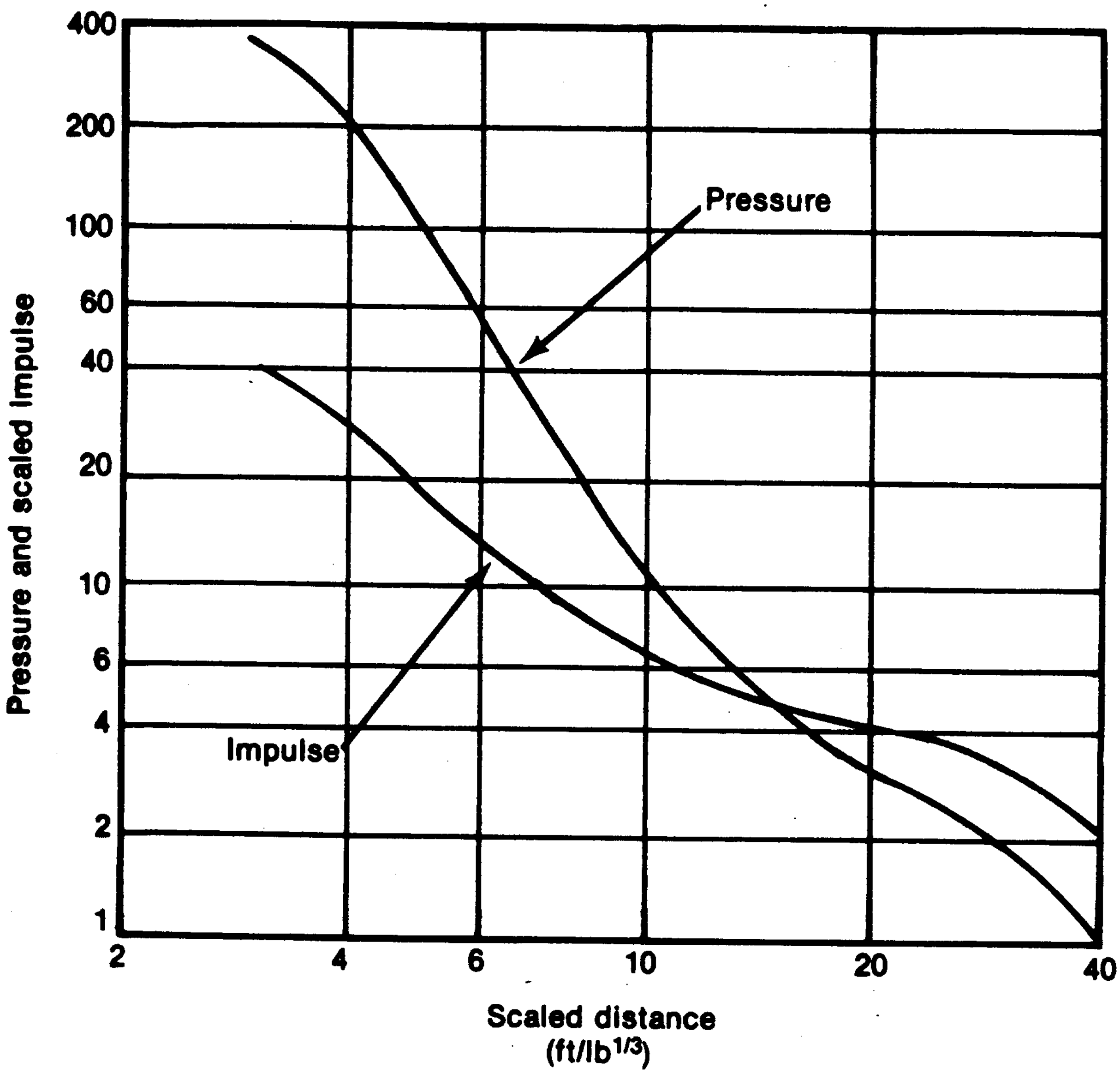


Figure 64. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for LX-14 in Orthorhombic Containers, L/D = 0.4:1.

Table 17. Summary of Results of Hemispherical Surface Bursts, Peak Pressure and Scaled Positive Impulse Values for, LX-14 Pressed Billets L/D = 2:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	279.27	1925.56	12.66	113.65	22.000	8.727	3.78	26.07	3.00	26.89
4.000	1.587	148.28	1022.40	26.73	234.45	23.000	9.124	3.52	24.25	2.84	25.46
5.000	1.983	85.90	592.31	28.16	252.74	24.000	9.521	3.28	22.63	2.69	24.17
6.000	2.380	54.49	375.74	24.39	218.90	25.000	9.917	3.07	21.18	2.56	23.00
7.000	2.777	37.28	257.07	19.70	176.82	26.000	10.314	2.88	19.87	2.44	21.92
8.000	3.174	27.09	186.80	15.72	141.06	27.000	10.711	2.71	18.68	2.33	20.92
9.000	3.570	20.65	142.37	12.66	113.64	28.000	11.108	2.55	17.59	2.23	19.98
10.000	3.967	16.35	112.71	10.39	93.23	29.000	11.504	2.41	16.59	2.13	19.09
11.000	4.364	13.34	91.99	8.70	78.04	30.000	11.901	2.27	15.67	2.03	18.26
12.000	4.760	11.16	76.95	7.42	66.60	31.000	12.298	2.15	14.82	1.95	17.46
13.000	5.157	9.53	65.69	6.45	57.87	32.000	12.694	2.03	14.03	1.86	16.69
14.000	5.554	8.27	57.01	5.69	51.08	33.000	13.091	1.93	13.29	1.78	15.95
15.000	5.950	7.28	50.17	5.09	45.71	34.000	13.488	1.83	12.60	1.70	15.24
16.000	6.347	6.48	44.66	4.61	41.39	35.000	13.884	1.73	11.95	1.62	14.56
17.000	6.744	5.82	40.15	4.22	37.86	36.000	14.281	1.65	11.35	1.55	13.89
18.000	7.141	5.28	36.38	3.89	34.93	37.000	14.678	1.56	10.78	1.48	13.25
19.000	7.537	4.82	33.20	3.62	32.45	38.000	15.075	1.49	10.24	1.41	12.62
20.000	7.934	4.42	30.48	3.38	30.34	39.000	15.471	1.41	9.73	1.34	12.02
21.000	8.331	4.08	28.13	3.18	28.51	40.000	15.868	1.34	9.25	1.27	11.43

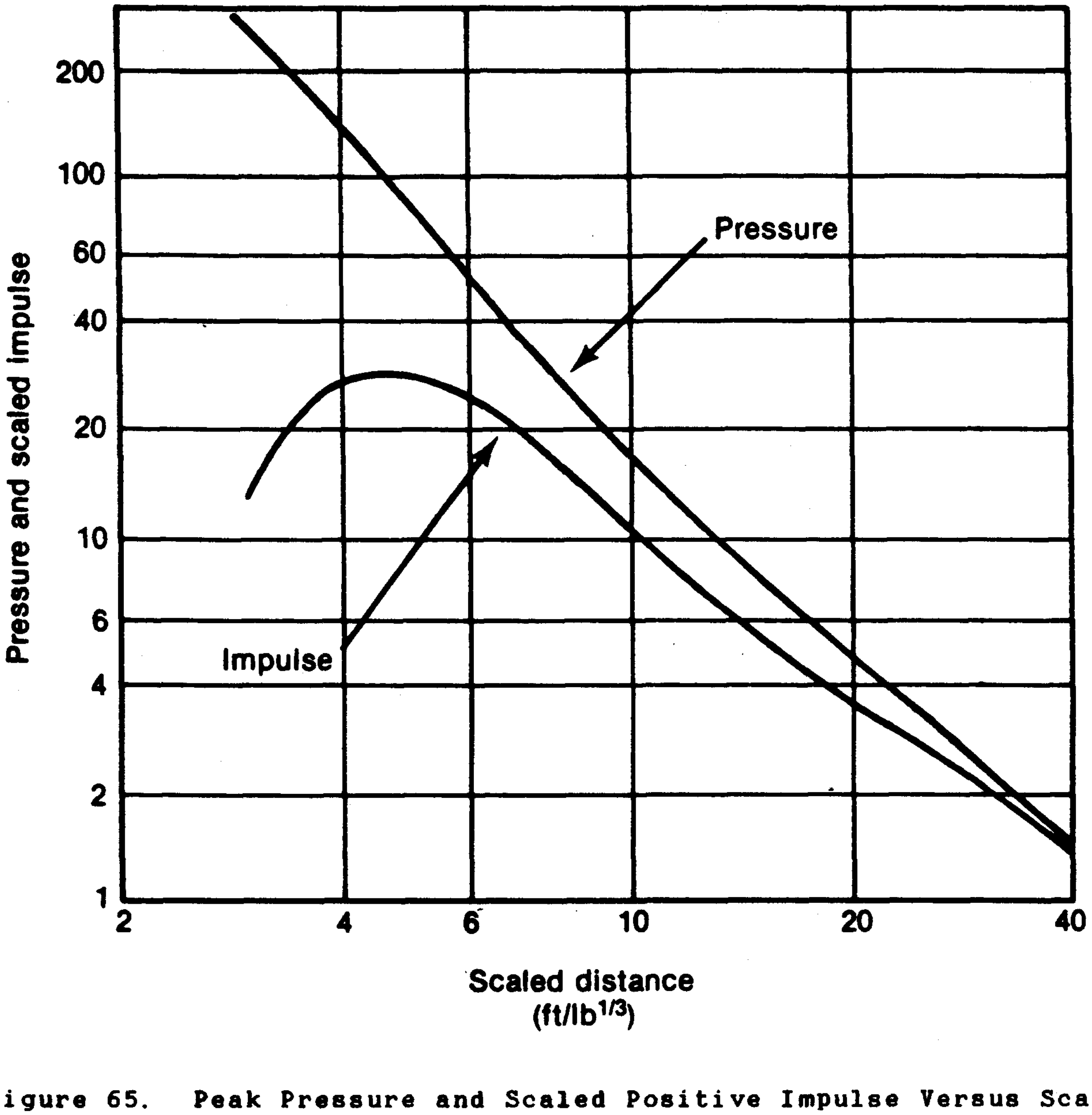


Figure 65. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for LX-14 Pressed Billets, L/D = 2:1.

Table 18. Summary of Results of Hemispherical Surface Bursts, Peak Pressure and Scaled Positive Impulse for LX-14 in Orthorhombic Containers, L/D = 0.6:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse psi · ms / $lb^{1/3}$	Scaled Impulse kPa · ms / $kg^{1/3}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse psi · ms / $lb^{1/3}$	Scaled Impulse kPa · ms / $kg^{1/3}$
3.000	1.190	338.88	2336.55	28.36	254.51	22.000	8.727	4.38	30.18	2.32	20.81
4.000	1.587	129.33	891.70	23.93	214.74	23.000	9.126	4.03	27.29	2.20	19.73
5.000	1.983	73.31	505.44	19.26	172.81	24.000	9.521	3.73	25.72	2.09	18.80
6.000	2.380	49.56	341.70	15.45	138.62	25.000	9.917	3.47	23.90	2.00	17.97
7.000	2.777	36.70	253.06	12.53	112.41	26.000	10.314	3.23	22.30	1.92	17.25
8.000	3.174	28.66	197.60	10.31	92.56	27.000	10.711	3.03	20.89	1.85	16.61
9.000	3.570	23.15	159.59	8.63	77.45	28.000	11.108	2.85	19.65	1.79	16.84
10.000	3.967	19.14	131.94	7.33	65.80	29.000	11.504	2.69	18.54	1.73	15.54
11.000	4.364	16.10	110.99	6.32	56.70	30.000	11.901	2.55	17.57	1.68	15.10
12.000	4.760	13.73	94.60	5.52	49.50	31.000	12.298	2.42	16.70	1.64	14.70
13.000	5.157	11.84	81.62	4.87	43.72	32.000	12.694	2.31	15.92	1.60	14.36
14.000	5.554	10.31	71.06	4.35	39.03	33.000	13.091	2.31	15.23	1.57	14.05
15.000	5.950	9.05	62.40	3.92	35.17	34.000	13.488	2.12	14.61	1.53	13.77
16.000	6.347	8.01	55.21	3.56	31.97	35.000	13.884	2.04	14.06	1.51	13.53
17.000	6.744	7.13	49.19	3.26	29.29	36.000	14.281	1.97	13.57	1.48	13.31
18.000	7.141	6.40	44.11	3.01	27.03	37.000	14.678	1.90	13.13	1.46	13.13
19.000	7.537	5.77	39.79	2.80	25.11	38.000	15.075	1.85	12.74	1.44	12.96
20.000	7.934	5.24	36.10	2.61	23.46	39.000	15.471	1.80	12.39	1.43	12.82
21.000	8.331	4.77	32.92	2.46	22.31	40.000	15.868	1.75	12.08	1.42	12.70

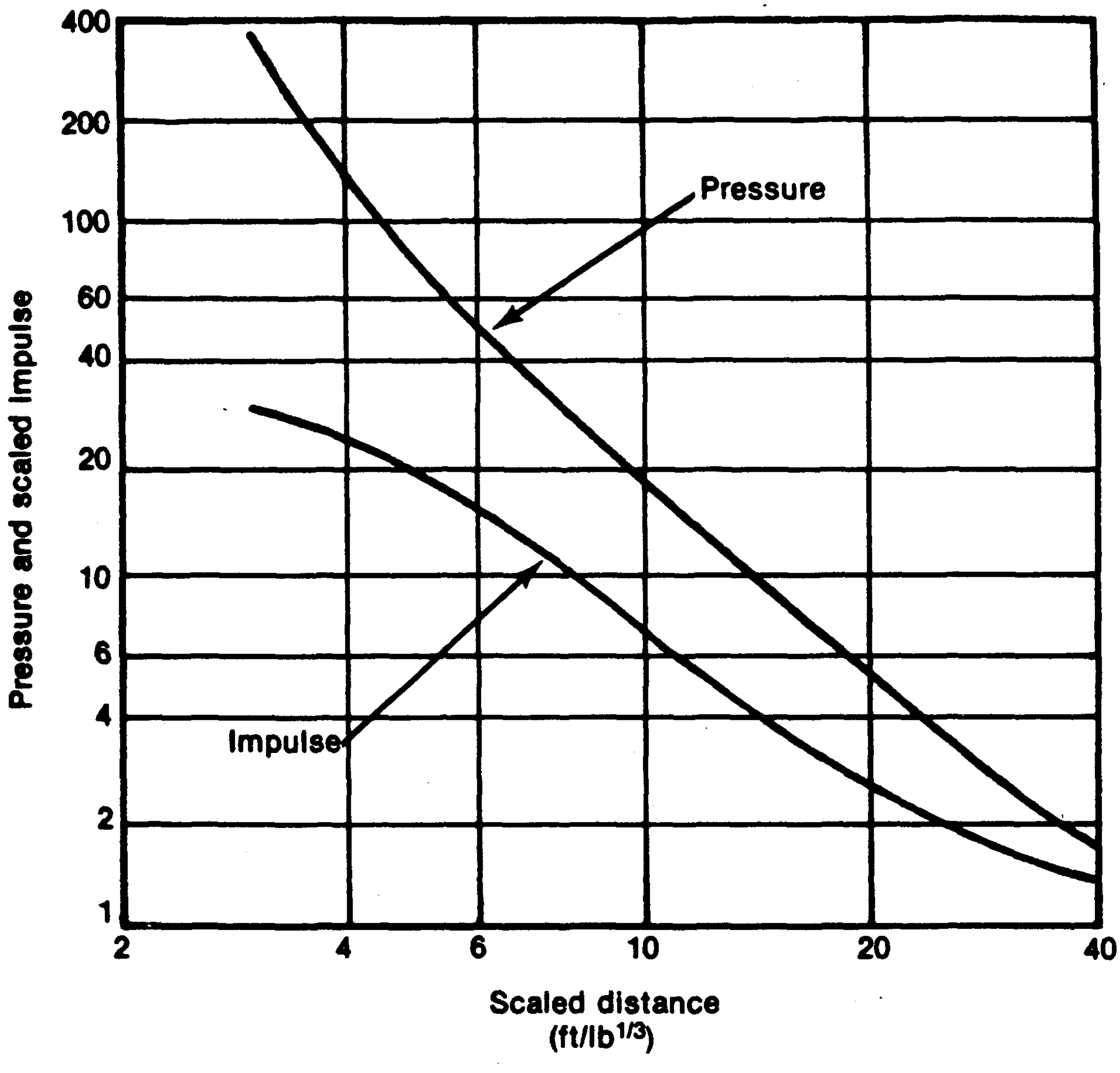


Figure 66. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for LX-14 in Orthorhombic Containers, L/D = 0.6:1.

OBJECTIVE

The objective of this study was to determine the maximum blast pressure output from the detonation of nitrocellulose in in-process manufacturing configurations and standard shipping containers. The measured pressure and impulse data were compared with known characteristics of hemispherical TNT data to determine TNT equivalency of nitrocellulose.

MATERIAL

The test material was dehydrated nitrocellulose (13.5% nitrogen) MIL standrad MIL-N-244A, Grade C. The nitrocellulose as received contained approximately 25% alcohol and was decanted to approximately 14% prior to test.

TEST SETUP

Nitrocellulose was tested in orthorhombic and cylindrical configurations in quantities of 11.3, 19.5, 22.7, 45.0 and 63.5 kg (25, 43, 50, 99 and 140 lb). Physical characteristics of the test configurations are described as folows:

(1) Nitrocellulose in 11.3, 22.7 and 63.5 kg (25, 50 and 140 lb) quantities was tested in cylindrical containers.

(2) Nitrocellulose in 19.5 kg (43 lb) quantities was tested in an orthorhombic container.

(3) Nitrocellulose in 45.0 kg (99 lb) quantities was placed in an orthorhombic plywood container with a height to length ratio of 0.25:1 was tested to simulate a Thermal Dehydration Unit.

All test charges were placed on a 1010 cold-rolled carbon steel witness plate and initiated by a booster charge of Composition C4 and a J2 engineers' special blasting cap.

INSTRUMENTATION

Twelve side-on piezoelectric pressure transducers were mounted flush to the ground surface in a 90-degree array. Scaled distances ranging from 1.19 to 15.87 $m/kg^{1/3}$ (3.0 to 40.0 $ft/lb^{1/3}$) were held constant throughout the experiments.

RESULTS

Peak pressure and scaled positive impulse values for the combined results of the cylindrical container configurations are given in Table 19 and Figure 67. The orthorhombic configuration pressure and scaled positive impulse values with a L/D ratio of 1:1 are given in Table 20 and Figure 68. The thermal dehydration unit tests of nitrocellulose in an orthorhombic configuration with a L/D ratio Of 0.08:1 are given in

Table 21 and Figure 69.

DISCUSSION

Pressure values for the cylindrical tests scaled as a function of the cube root of the charge weight. All values from all of the cylindrical configuration tests were combined for statistical validity. The pressure values were greater than expected at all scaled distances equal to or less than 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$) and less than expected at a scaled distance of 15.87 $m/kg^{1/3}$ (40.0 $ft/lb^{1/3}$). The pressure values were 1290, 540, 254, 87 23, and 7.6 kPa (187.1, 78.3, 36.9, 12.6, 3.4, and 1.1 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These values equate to 1.6, 1.2, 1.0, 1.1, 1.0, and 0.8 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were slightly greater than expected at a scaled distance of 1.19 $m/kg^{1/3}$ (3.0 $ft/lb^{1/3}$) and less than expected at all other scaled distances of the experiment. The scaled positive impulse values were 185, 124, 91, 60, 31, and 14.4 kPa-ms/$kg^{1/3}$ (20.7, 13.8, 10.1, 6.6, 3.5, and 1.6 psi-ms/$lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 1.1, 0.9, 0.8, 0.8, 0.8, and 0.8 times equal amounts of TNT at the same scaled distances, respectively.

Pressure values for the Thermal Dehydration Unit tests were greater than expected at a scaled distance of 1.19 $m/kg^{1/3}$ (3.0 $ft/lb^{1/3}$) and less than expected at all other scaled distances of the experiment. The pressure values were 1056, 434, 191, 61, 20, and 7.9 kPa (153.2, 63.0, 27.7, 8.8, 2.9, and 1.15 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 1.3, 0.8, 0.6, 0.6, 0.7, and 0.9 times equal amounts of TNT at the same scaled distances, respectively. Scaled Positive impulse values were equal to or less than expected values at all scaled distances of the experiment. The scaled positive impulse values were 144, 101, 75, 55, 37, and 15.2 kPa-ms/$kg^{1/3}$ (16.1, 11.2, 8.4, 6.1, 4.1, and 1.7 psi-ms/$lb^{1/3}$), respectively. These scaled positive impulse values equate to 0.8, 0.6, 0.6, 0.7, 1.0, and 0.8 times equal amounts of TNT at the same scaled distances, respectively.

Pressure values for the orthorhombic test configuration with a L/D ratio of 1:1 were greater than expected at all scaled distances equal to or less than 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$) and less than expected at a scaled distance of 15.87 $m/kg^{1/3}$ (40.0 $ft/lb^{1/3}$). The pressure values were 1116, 572, 268, 81, 26, and 7.7 kPa (161.8, 82.9, 38.8, 11.8, 3.8, and 1.11 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14 and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 1.3, 1.2, 1.2, 1.0, 1.2, and 0.9 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were greater than expected at scaled distances equal to or less than 7.14 m/kg^1/3 (18.0 ft/lb^1/3) and less than expected at a scaled distance of 15.87 $m/kg^{1/3}$ (40.0 $ft/lb^{1/3}$). The scaled positive impulse values were 153, 121, 99, 61, 34, and 17.2 kPa-ms/$kg^{1/3}$ (17.07, 13.39, 11.09, 6.75, 3.76, and 1.92 psi-ms/$lb^{1/3}$)

at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 1.1, 0.9, 0.8, 0.8, 0.8, and 0.8 times equal amounts of TNT at the same scaled distance, respectively.

CONCLUSIONS

(1) To within experimental limits the nitrocellulse scaled as a function of the cube root of the charge weight.

(2) Pressure and scaled positive impulse values varied as a function of the test configuration (geomerty).

Table 19. Summary of Results of Hemishperical Surface Bursts, Peak Pressure, and Impulse Values for Nitrocellulose in Cylindrical Container, L/D = 1:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	187.14	1290.31	20.65	185.28	22.000	8.727	2.39	16.49	2.90	26.02
4.000	1.587	78.31	539.93	13.84	124.23	23.000	9.124	2.22	15.32	2.74	24.63
5.000	1.983	44.31	305.53	10.91	97.87	24.000	9.521	2.07	14.30	2.63	23.58
6.000	2.380	29.15	201.00	9.23	82.79	25.000	9.917	1.95	13.41	2.52	22.61
7.000	2.777	20.93	144.29	8.09	72.62	26.000	10.314	1.83	12.63	2.42	21.71
8.000	3.174	15.89	109.56	7.25	65.06	27.000	10.711	1.73	11.93	2.33	20.89
9.000	3.570	12.55	86.51	6.58	59.05	28.000	11.108	1.64	11.31	2.24	20.13
10.000	3.967	10.20	70.31	6.03	54.09	29.000	11.504	1.56	10.77	2.16	19.56
11.000	4.364	8.48	58.44	5.56	49.87	30.000	11.901	1.49	10.28	2.09	18.78
12.000	4.760	7.17	49.46	5.15	46.23	31.000	12.298	1.43	9.84	2.03	18.17
13.000	5.157	6.16	42.48	4.80	43.03	32.000	12.694	1.37	9.45	1.96	17.61
14.000	5.554	5.36	36.96	4.48	40.21	33.000	13.091	1.32	9.09	1.90	17.09
15.000	5.950	4.71	32.50	4.20	37.69	34.000	13.488	1.27	8.78	1.85	16.61
16.000	6.347	4.19	28.86	3.95	35.44	35.000	13.884	1.23	8.49	1.80	16.16
17.000	6.744	3.75	25.85	3.72	33.41	36.000	14.281	1.19	8.24	1.75	15.74
18.000	7.141	3.38	23.33	3.52	31.58	37.000	14.678	1.16	8.01	1.71	15.35
19.000	7.537	3.07	21.20	3.33	29.92	38.000	15.075	1.13	7.80	1.67	14.99
20.000	7.934	2.81	19.39	3.17	28.41	39.000	15.471	1.10	7.61	1.63	14.65
21.000	8.331	2.59	17.83	3.01	27.04	40.000	15.868	1.08	7.45	1.60	14.33

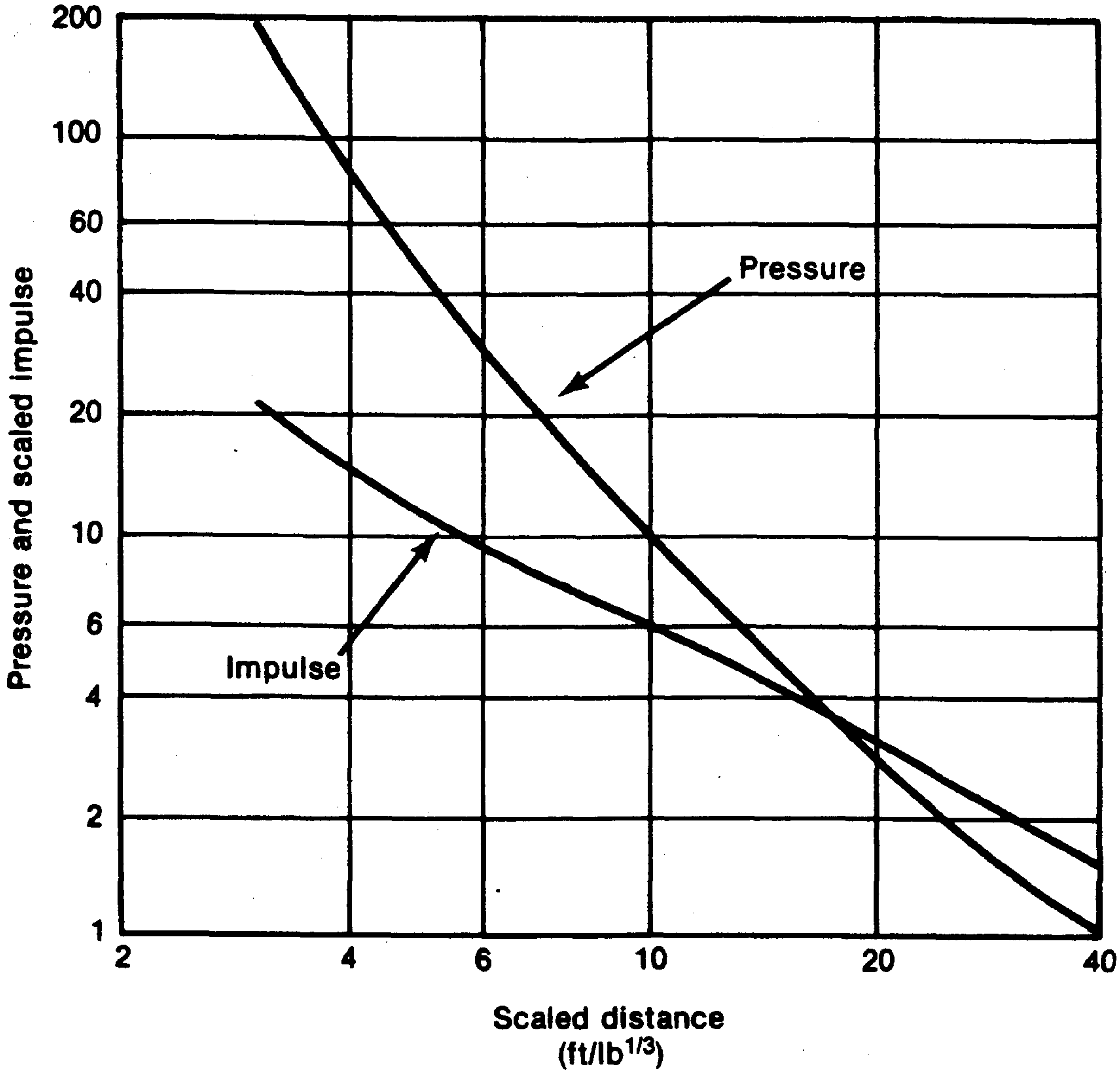


Figure 67. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for Nitrocellulose in Cylindrical Containers, L/D = 1:1.

Table 20. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for Nitrocellulose in Dryer Bed Configuration, L/D = 0.08:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	153.20	1056.34	16.07	144.23	22.000	8.727	2.26	15.56	3.50	31.41
4.000	1.587	62.97	434.20	11.26	101.06	23.000	9.124	2.14	14.77	3.37	30.21
5.000	1.983	33.79	232.99	9.08	81.41	24.000	9.521	2.04	14.05	3.24	29.06
6.000	2.380	21.26	144.58	7.85	70.49	25.000	9.917	1.95	13.41	3.11	27.99
7.000	2.777	14.83	102.26	7.07	63.43	26.000	10.314	1.86	12.83	3.00	26.88
8.000	3.174	11.11	76.62	6.51	58.44	27.000	10.711	1.78	12.29	2.88	25.84
9.000	3.570	8.76	60.43	6.09	54.64	28.000	11.108	1.71	11.80	2.77	24.84
10.000	3.967	7.18	49.53	5.75	51.59	29.000	11.504	1.65	11.35	2.66	23.88
11.000	4.344	6.06	41.81	5.46	49.02	30.000	11.901	1.59	10.93	2.56	22.94
12.000	4.760	5.24	36.11	5.21	44.77	31.000	12.298	1.53	10.54	2.46	22.05
13.000	3.157	4.41	31.76	4.99	44.76	32.000	12.694	1.48	10.18	2.36	21.18
14.000	5.554	4.11	28.36	4.78	42.92	33.000	13.091	1.43	9.84	2.27	20.34
15.000	5.950	3.72	25.63	4.59	41.21	34.000	13.488	1.38	9.52	2.18	19.54
16.000	6.347	3.39	23.39	4.41	39.61	35.000	13.884	1.34	9.22	2.09	18.76
17.000	6.744	3.12	21.54	4.24	38.09	36.00	14.281	1.30	8.93	2.01	18.01
18.000	7.141	2.90	19.97	4.08	34.44	37.000	14.678	1.26	8.66	1.93	17.30
19.000	7.537	2.70	18.63	3.93	35.25	38.000	15.075	1.22	8.41	1.85	16.60
20.000	7.934	2.53	17.47	3.78	33.92	39.000	15.471	1.18	8.16	1.78	15.94
21.000	8.331	2.39	16.46	3.64	32.64	40.000	15.8668	1.15	7.93	1.70	15.30

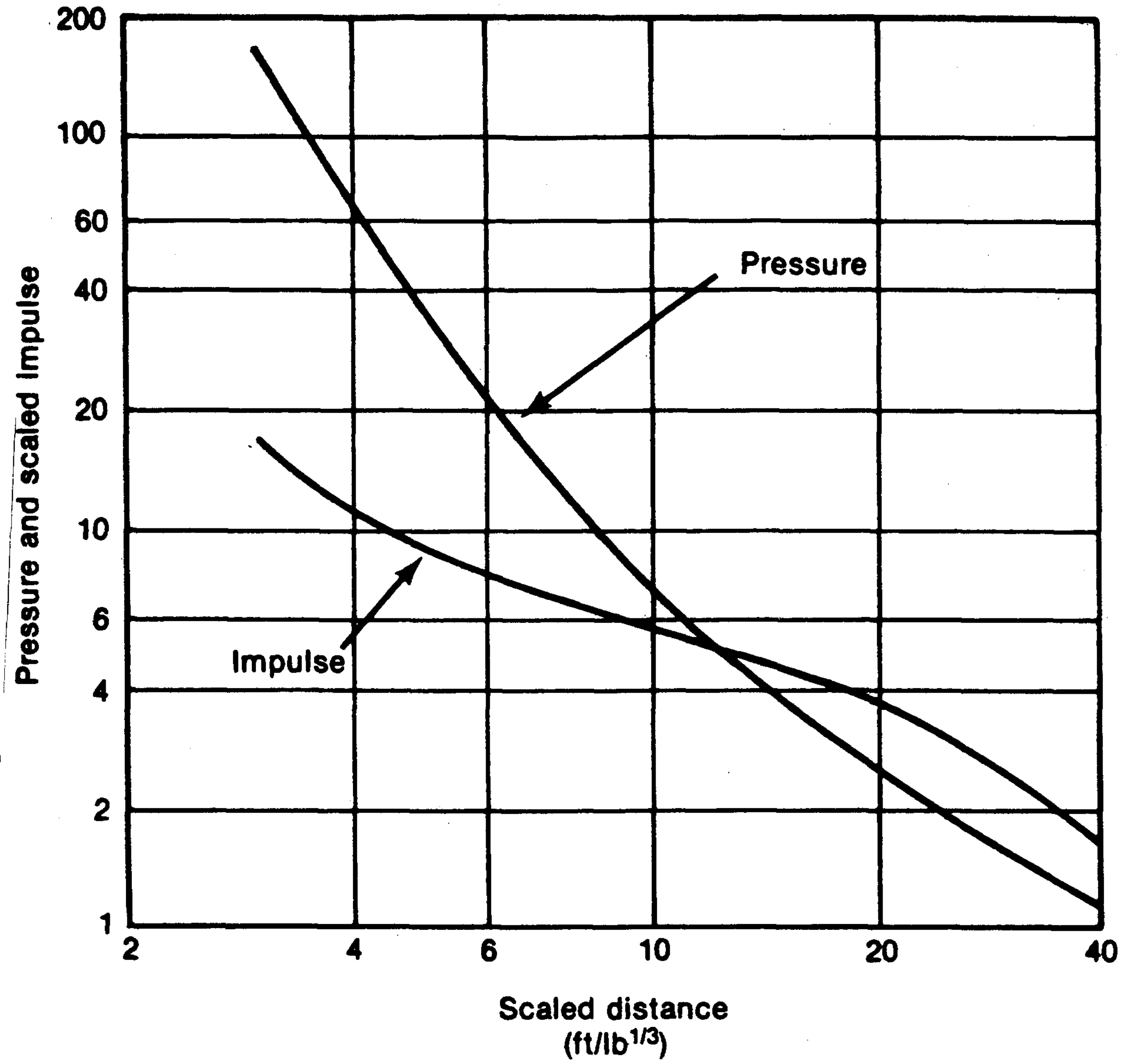


Figure 68. Peak Pressure and Scaled Positive Impulse Versus Scale Distance for Nitrocellulose in Dryer Bed Configuration, L/D = 0.08:1.

Table 21. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for Nitrocellulose in Orthorhombic Configuration, L/D = 1.2:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	161.77	1115.41	17.07	153.22	22.000	8.727	2.89	19.94	3.17	28.47
4.000	1.587	82.92	571.73	13.39	120.17	23.000	9.124	2.73	18.82	3.06	27.43
5.000	1.983	47.16	325.14	11.09	99.52	24.000	9.521	2.58	17.79	2.95	26.46
6.000	2.380	29.82	205.64	9.51	85.32	25.000	9.917	2.44	16.85	2.85	25.56
7.000	2.777	20.57	141.86	8.35	74.90	26.000	10.314	2.32	15.97	2.76	24.73
8.000	3.174	15.19	104.73	7.46	66.92	27.000	10.711	2.20	15.16	2.67	23.95
9.000	3.570	11.82	81.49	6.75	60.58	28.000	11.108	2.09	14.39	2.59	23.23
10.000	3.967	9.58	66.05	6.18	55.42	29.000	11.504	1.98	13.67	2.51	22.55
11.000	4.344	8.02	55.29	5.70	51.13	30.000	11.901	1.88	12.98	2.44	21.91
12.000	4.760	6.88	47.47	5.29	47.51	31.000	12.298	1.79	12.33	2.38	21.31
13.000	5.157	6.03	41.58	4.95	44.41	32.000	12.494	1.70	11.72	2.31	20.75
14.000	5.554	5.37	37.02	4.65	41.71	33.000	13.091	1.61	11.13	2.25	20.22
15.000	5.950	4.84	33.40	4.38	39.35	34.000	13.488	1.53	10.57	2.20	19.71
16.000	6.347	4.42	30.44	4.15	37.26	35.000	13.884	1.45	10.03	2.14	19.24
17.000	6.744	4.06	27.99	3.94	35.40	36.000	14.281	1.38	9.52	2.09	18.78
18.000	7.141	7.36	25.91	3.76	33.73	37.000	14.678	1.31	9.02	2.05	18.36
19.000	7.537	3.50	24.12	3.59	32.23	38.000	15.075	1.24	8.55	2.00	17.95
20.000	7.934	3.27	22.56	3.44	30.86	39.000	15.471	1.18	8.11	1.96	17.56
21.000	8.331	3.07	21.18	3.30	29.62	40.000	15.868	1.11	7.67	1.92	17.19

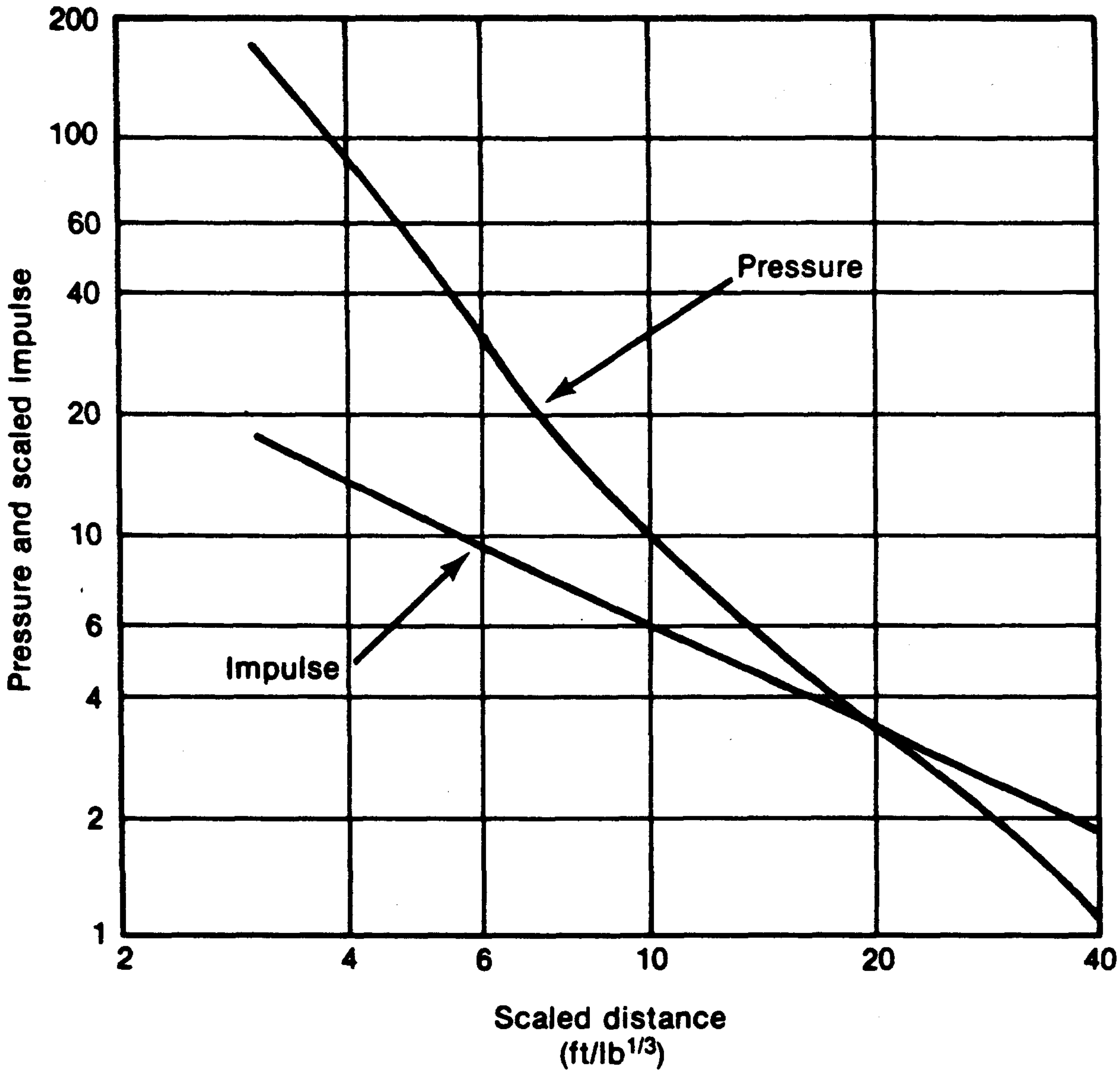


Figure 69. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for Nitrocellulose in Orthorhombic Containers, L/D = 1.2:1.

NITROGLYCERINE[13]

OBJECTIVE

The objective of this study was to experimentally determine the TNT equivalency of nitroglycerine in terms of peak pressure and scaled positive impulse. The output blast parameters were compared with known characteristics of hemispherical TNT to determine the TNT equivalency of nitroglycerine.

MATERIAL

Nitroglycerine is a liquid high explosive which was received and tested at the Badger Army Ammunition Plant. Quantities tested were 0.45, 0.9, and 1.81 kg (1, 2 and 4 lb).

TEST SETUP

The test material was hand-carried from the operating facility to the test site. Polymethylpentene plastic laboratory beakers in 400, 600, and 2000 ml sizes holding 0.45, 0.91, and 1.8 kg (1, 2, and 4 lb) quantities, respectively, representing a L/D ratio of 1:1, were used to hold the test material. A copper mesh screen was formed and placed into the liquid so that the booster charge and initiator would rest slightly submerged and in the center of the material. The beaker containing the explosive and the booster charge were placed at ground zero on a steel witness plate. The witness plate had welded steel stakes which were driven into the ground. A ground strap was affixed to the copper screen and steel stakes on the witness plate. A cylindrical Composition C4 booster charge was wrapped in a plastic bag along with a number 6 electric blasting cap. The booster charge and the initiator were wrapped in plastic to prevent contamination.

INSTRUMENTATION

Six Photocon model 752A pressure transducers were flush mounted on the ground. They were located at intervals on a radial line from ground zero at scaled distances ranging from 1.59 to 19.84 $m/kg^{1/3}$ (4.0 to 50 $ft/lb^{1/3}$).

RESULTS

Test results of the combined charge weights of nitroglycerine are shown in Table 22 and Figure 70. The results were combined because of statistical validity and because the pressure and impulse values scaled as a function of the cube root of the charge weights.

DISCUSSION

The pressure values for the combined charge weights were equal to or greater than expected at scaled distances equal to or less than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$) and less than expected at scaled distances equal to or greater than 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$). The pressure values were 2541, 936, 363, 90, 22, and 7.1 kPa (368.6, 135.8, 52.6, 13.1, 3.12

and 1.03 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 4.0, 2.5, 1.7, 1.2, 0.8, and 0.7 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were equal to or greater than expected at all scaled distances. The scaled positive impulse values were 248, 172, 124, 76, 41, and 19.7 kPa-ms/kg$^{1/3}$ (27.6, 19.2, 13.8, 8.5, 4.6, and 2.14 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 1.9, 1.4, 1.3, 1.1, 1.2, and 1.2 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) Nitroglycerine, a very sensitive explosive, yields a large explosive output when initiated.

(2) The explosive output of nitroglycerine does not change with variations in the magnitude of ignition stimulus.

(3) The explosive output of nitroglycerine does not change with variations in the magnitude of the charge weight.

Table 22. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse Values for Nitroglycerine in Cylindrical Containers, L/D = 1:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	368.59	2541.40	27.63	247.99	22.000	8.727	2.25	15.48	3.85	34.51
4.000	1.587	135.82	936.49	19.21	172.43	23.000	9.124	2.10	14.47	3.69	33.12
5.000	1.983	66.48	458.37	14.98	134.43	24.000	9.521	1.97	13.58	3.55	31.83
6.000	2.380	38.60	266.11	12.42	111.49	25.000	9.917	1.86	12.80	3.41	30.63
7.000	2.777	25.07	172.88	10.70	98.02	26.000	10.314	1.76	12.10	3.29	29.51
8.000	3.174	17.62	121.52	9.45	84.79	27.000	10.711	1.67	11.49	3.17	28.47
9.000	3.570	13.13	90.50	8.49	76.21	28.000	11.108	1.59	10.93	3.06	27.49
10.000	3.967	10.21	70.42	7.73	69.38	29.000	11.504	1.51	10.43	2.96	26.57
11.000	4.364	8.22	56.70	7.11	63.79	30.000	11.901	1.45	9.98	2.86	25.70
12.000	4.760	6.80	46.91	6.59	59.11	31.000	12.298	1.39	9.57	2.77	24.88
13.000	5.157	5.76	39.69	6.14	52.12	32.000	12.694	1.33	9.20	2.69	24.11
14.000	5.554	4.96	34.19	5.76	51.66	33.000	13.091	1.28	8.85	2.61	23.38
15.000	5.950	4.34	29.91	5.42	48.63	34.000	13.488	1.24	8.54	2.53	22.68
16.000	6.347	3.84	26.51	5.12	45.95	35.000	13.884	1.20	8.25	2.45	22.03
17.000	6.744	3.45	23.76	4.85	43.55	36.000	14.281	1.16	7.98	2.38	21.40
18.000	7.141	3.12	21.49	4.61	41.39	37.000	14.678	1.12	7.73	2.32	20.80
19.000	7.537	2.84	19.60	4.39	39.43	38.000	15.075	1.09	7.50	2.25	20.23
20.000	7.934	2.61	18.01	4.20	37.65	39.000	15.471	1.06	7.28	2.19	19.69
21.000	8.331	2.41	16.65	4.01	36.01	40.000	15.868	1.03	7.08	2.14	19.17

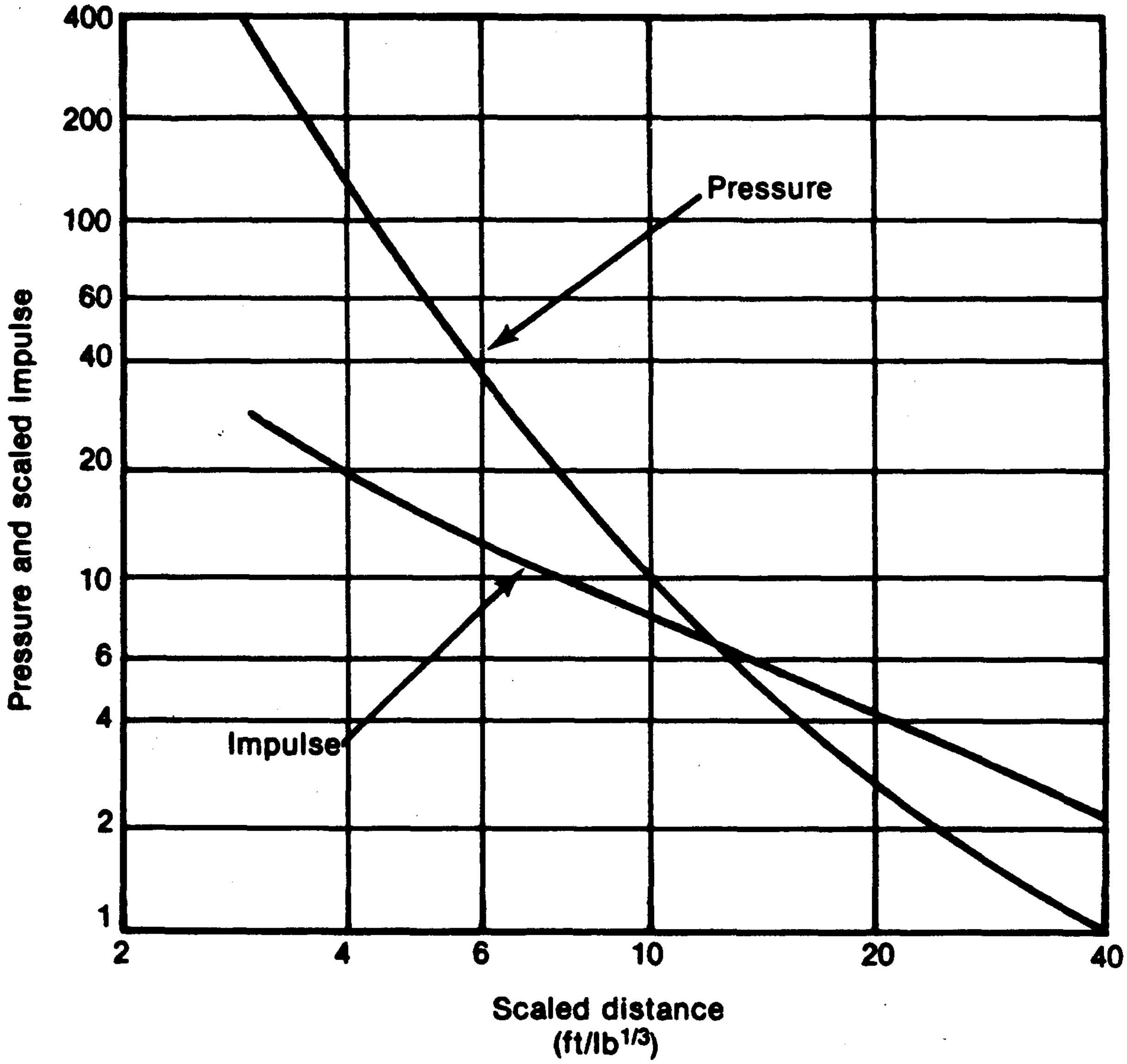


Figure 70. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for Nitroglycerine in Cylindrical Containers, L/D = 1:1.

OBJECTIVE

The objective of this study was to measure the maximum pressure and positive impulse of nitroguanidine and compare the results directly with hemispherical TNT to determine TNT equivalency.

MATERIAL

Nitroguanidine was received in bulk powder form and was tested in 2.7, 10.9, 22.7 and 49.9 kg (5.86, 24.0, 50 and 110 lb) quantities. The apparent bulk density was 0.24 g/cm^3.

TEST SETUP

Aluminum walled cylinders were spot-welded together with aluminum angles. The cylinders length to diameter ratio for each simulation test was 1:1. The end plates of the cylinders had a circular hole with an area of 1/8 the cross-section area. The thickness of the scaled cylinders were also scaled.

The scaled storage bins were placed on a steel witness plate and the booster charge size was determined accordingly. Both tetryl and Composition C4 were used as boosters. The booster was embedded in the center of the charge at the bottom of the bin.

INSTRUMENTATION

Six pressure transducers were installed flush with the top surface of the concrete slab. Radial distance of the pressure transducers varied as a function of the charge weight, but the scaled distances ranging from 1.19 to 15.87 m/kg$^{1/3}$ (3.0 to 40.0 ft/lb$^{1/3}$) were held constant throughout the experiments.

RESULTS

Pressure and scaled positive impulse values from all tests were combined because the charge weights scaled as a function of the cube root scaling law and to provide statistical validity. Test results of the combined values are shown in Table 23 and Figure 71.

DISCUSSION

The pressure values for the combined charge weights and configurations with a L/D=1:1 were equal to or greater than expected at scaled distances equal to or less than 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$) and less than expected at scaled distances equal to or greater than 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$). The pressure values were 1045, 571, 290, 88, 20, and 6.3 kPa (151.6, 82.8, 42.1, 12.8, 2.9, and 0.92 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These values equate to 1.1, 1.3, 1.3, 0.9, 0.8, and 0.6 times equal amounts of TNT at the same scaled distances respectively. Scaled positive impulse values were greater than expectes at scaled distances equal to or less than 2.14 $m/kg^{1/3}$ and less than expected at scaled distances equal to or greater than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$). The scaled positive impulse values were 160, 152,119, 60, 22, and 14.9 $kPa\text{-}ms/kg^{1/3}$ (17.8, 16.9, 13.3, 6.7, 2.4 and 1.66 $psi\text{-}ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 1.1, 1.3, 1.0, 0.9, 0.4, and 0.7 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) Nitroquanidine is less sensitive to shock initiation than TNT or most other explosive materials.

(2) Once initiated, nitroguanidine can produce signifantly higher peak pressure and impulse at close in scaled distances.

(3) Nitroguanidine appears to follow the cube root scaling laws.

Table 23. Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse Values for, Nitroguanidine, L/D ratio = 1:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	151.60	1045.26	17.88	160.43	22.000	8.727	2.02	13.96	1.90	17.09
4.000	1.587	82.76	570.65	16.97	152.28	23.000	9.124	1.88	12.95	1.82	16.36
5.000	1.983	50.18	346.01	14.40	129.25	24.000	9.521	1.75	12.09	1.75	15.63
6.000	2.380	32.95	227.19	11.84	106.27	25.000	9.917	1.64	11.33	1.70	15.22
7.000	2.777	23.00	158.59	9.71	87.14	26.000	10.314	1.55	10.67	1.65	14.77
8.000	3.174	16.85	116.16	8.03	72.07	27.000	10.711	1.46	10.09	1.60	14.40
9.000	3.570	12.83	84.44	6.73	60.38	28.000	11.108	1.39	9.58	1.57	14.08
10.000	3.967	10.08	69.50	5.72	51.31	29.000	11.504	1.32	9.12	1.53	13.77
11.000	4.364	8.13	56.47	4.93	44.21	30.000	11.901	1.26	8.72	1.52	13.60
12.000	4.760	6.17	46.24	4.30	38.61	31.000	12.298	1.21	8.36	1.50	13.43
13.000	5.157	5.64	38.87	3.80	34.14	32.000	12.694	1.16	8.03	1.48	13.30
14.000	5.554	4.82	33.21	3.40	30.53	33.000	13.091	1.12	7.74	1.47	13.20
15.000	5.950	4.17	28.78	3.08	27.60	34.000	13.488	1.08	7.48	1.46	13.13
16.000	6.347	3.66	25.25	2.81	25.18	35.000	13.884	1.05	7.24	1.46.	13.09
17.000	6.766	3.25	22.39	2.58	23.19	36.000	14.281	1.02	7.02	1.46	13.09
18.000	7.141	2.91	20.05	2.40	21.52	37.000	14.678	0.99	6.83	1.46	13.10
19.000	7.537	2.63	18.12	2.24	20.12	38.000	15.075	0.96	6.65	1.46	13.14
20.000	7.934	2.39	16.50	2.11	18.94	39.000	15.471	0.94	6.49	1.47	13.21
21.00	8.331	2.19	15.13	2.00	17.94	40.000	15.868	0.92	6.34	1.48	13.30

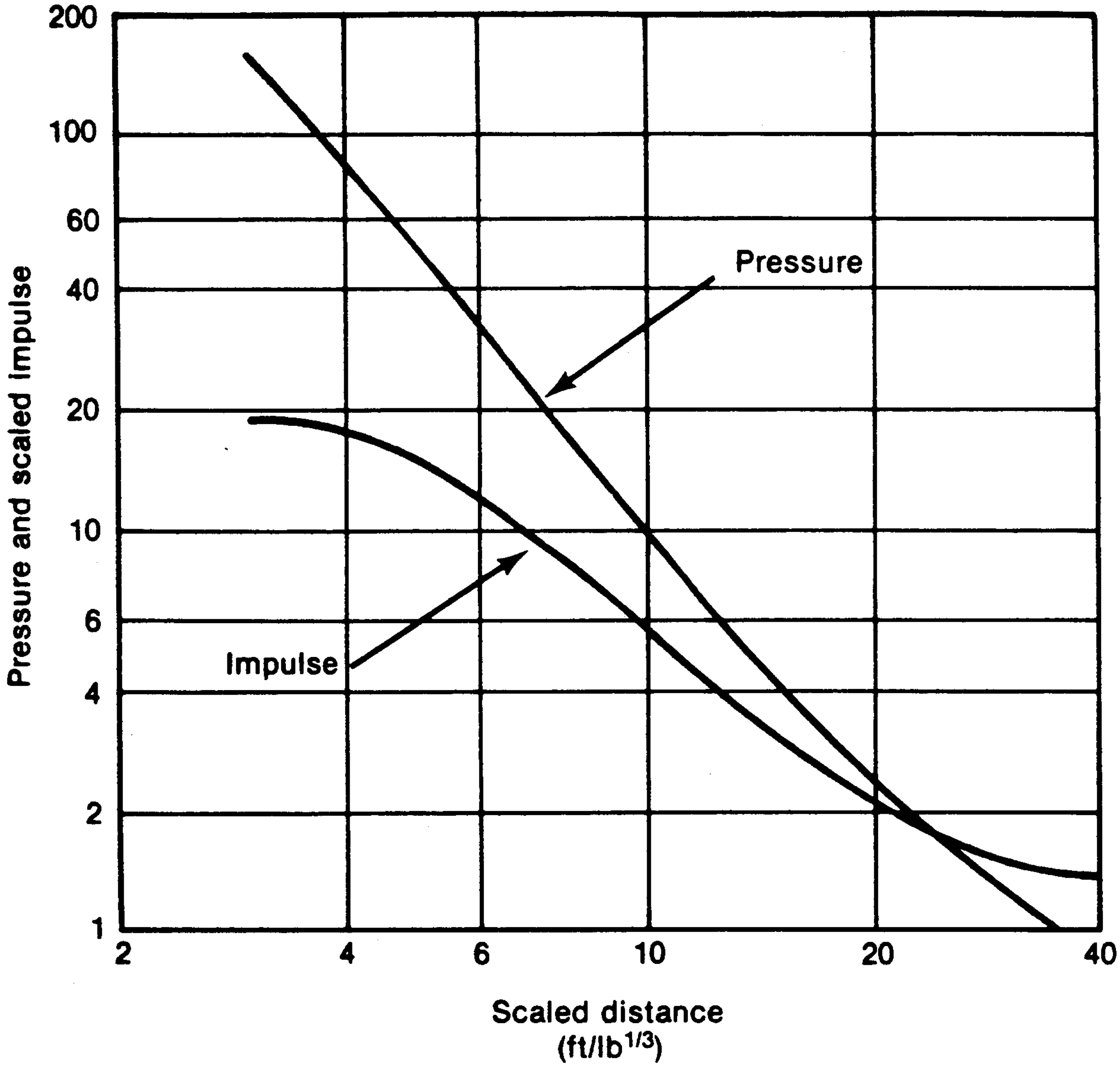


Figure 71. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for Nitroguanidine, L/D = 1:1.

OCTOL 75/25[14]

OBJECTIVE

The objective of this study was to determine the maximum output from the detonation of Octol 75/25 in terms of peak overpressure and positive impulse for in-plant process configurations. The measured parameters were compared with known characteristics of hemispherical TNT to determine TNT equivalency.

MATERIAL

Octol 75/25 is a high explosive consisting of 75% HMX and 25% TNT and is used as a casting explosive. Octol 75/25 was received in flake form in telescoping fiberboard containers.

TEST SETUP

In-process tests were conducted in those configurations which were considered as sensitive locations of the explosive manufacturer's facility. These configurations were a hopper at the end of a casting belt, a transfer box, and packout in standard shipping containers. The physical characteristics of the test configurations were as follows:

(1) Orthorhombic standard fiberboard shipping container with a L/D ratio of 0.5:1 containing 13.6 and 27.2 kg (30 and 60 lb) of explosives.

(2) Orthorhombic fiberboard transfer box with a L/D ratio of 0.8:1 containing 45.4 and 68.0 kg (100 and 150 lb) of explosives.

(3) A truncated prism (hopper) constructed from plywood with a L/D ratio of 2:1 containing 45.4 and 68.0 kg of explosives.

The test charges were initiated using Compositon C4 conical-shaped booster charges with a L/D ratio of 1:2 for the orthorhombic configurations and a L/D ratio of 1:4 was used for the truncated prism configuration. A J2 engineers' special blasting cap was used as the initiation source.

INSTRUMENTATION

Twelve side-on piezoelectric pressure transducers were mounted flush to the ground surface in a 90-degree array. Scaled distances ranging from 1.19 to 15.87 m/kg$^{1/3}$ (3.0 to 40.0 ft/lb$^{1/3}$) were held constant throughout the experiments.

RESULTS

Peak pressure and scaled positive impulse values for the combined results of the orthorhombic configuration tests are given in Table 24 and Figure 72. The truncated prism results are given in Table 25 and Figure 73. The values for each type of tests were combined for statistical validity and all data reported were within one standard deviation of the mean.

DISCUSSION

Peak pressure values for the orthorhombic configurations were greater than expected at all scaled distances of the experiment. Peak pressure values were 3056, 1563, 570, 107, 33, and 11.5 kPa (443.2, 226.7, 82.7, 15.5, 4.8, and 1.66 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These values equate to 5.2, 5.3, 2.9, 1.5, 1.6, and 2.2 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values for the orthorhombic configuration were greater than expected at all scaled distances of the experiment. The scaled positive impulse values were 346, 242, 170, 96, 48, and 23.3 $kPa\text{-}ms/kg^{1/3}$ (38.6, 27.0, 18.9, 10.7, 5.3, and 2.6 $psi\text{-}ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These values equate to 2.9, 2.8, 2.7, 1.3, 1.6, and 1.2 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the combined results of the truncated prism were equal to or greater than expected at all scaled distances of the experiment. The pressure values were 3613, 2085, 792, 137, 32, and 8.3 kPa (524.0, 302.4, 114.8, 19.8, 4.7, and 1.2 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14 and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These values equate to 6.5, 7.0, 5.3, 2.0, 1.5, and 1.0 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were greater than expected at all scaled distances equal to or less than 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$) and less than expected at a scaled distance of 15.87 $m/kg^{1/3}$ (40.0 $ft/lb^{1/3}$). The scaled positive impulse values were 371, 285, 207, 109, 39, and 9.6 $kPa\text{-}ms/kg^{1/3}$ (41.3, 31.8, 23.1, 12.2, 4.3 and 1.07 $psi\text{-}ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0 and 40.0, $ft/lb^{1/3}$), respectively. These values equate to 2.9, 3.3, 4.3, 1.5, 1.2, and 0.2 times equal amounts of TNT at the same scaled distances, respectively.

There are noted differences in the pressure and impulse values obtained for the orthorhombic and truncated prism tests. Higher pressures were achieved in the truncated prism tests at scaled distances equal to or less than 2.14 $m/kg^{1/3}$ (5.4 $ft/lb^{1/3}$) and lower impulse values for the truncated prism at the far-field scaled distance of the experiment. These differences were attributed to the test configurations (geometry). The same general trend has been noted on other similar experiments.

CONCLUSIONS

(1) Octol 75/25 when detonated in orthorhombic containers, produces greater values than an equivalent weight of TNT.

(2) Octol 75/25 when detonated in truncated prism configurations produces pressures greater than equal amounts of TNT at the same scaled distances.

(3) Blast output (peak pressure and positive impulse) for Octol 75/25 is dependant upon the configuration from which it is detonated.

(4) To within experimental error, blast pressure and impulse scale as a function of the cube-root scaling laws versus charge weight.

Table 24. Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse Values for Octol 75/25 in Orthorhombic Containers, L/D = 0.7:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	443.20	3055.88	38.61	346.47	22.000	8.727	3.78	26.06	4.37	39.22
4.000	1.587	226.67	1562.88	27.00	242.33	23.000	9.124	3.65	25.17	4.20	37.66
5.000	1.983	108.46	747.84	20.67	185.48	24.000	9.521	3.53	24.33	4.04	36.23
6.000	2.380	56.97	392.77	16.72	150.06	25.000	9.917	3.41	23.52	3.89	34.92
7.000	2.777	33.52	231.11	14.04	126.01	26.000	10.314	3.30	22.73	3.76	33.72
8.000	3.174	21.84	150.58	12.11	108.68	27.000	11.711	3.18	21.95	3.63	32.61
9.000	3.570	15.48	106.75	10.66	95.64	28.000	11.108	3.07	21.17	3.52	31.59
10.000	3.967	11.75	81.00	9.52	85.47	29.000	11.504	2.96	20.38	3.41	30.63
11.000	4.344	9.41	64.87	8.62	77.34	30.000	11.901	2.84	19.58	3.31	29.74
12.000	4.760	7.87	54.25	7.88	70.70	31.000	12.298	2.72	18.77	3.22	28.92
13.000	5.157	6.80	46.92	7.26	65.16	32.000	12.694	2.60	17.96	3.14	28.14
14.000	5.554	6.05	41.69	6.74	60.49	33.000	13.091	2.49	17.14	3.05	27.14
15.000	5.950	5.49	37.85	6.29	56.49	34.000	13.488	2.37	16.31	2.98	26.73
16.000	6.347	5.07	34.93	5.91	53.02	35.000	13.884	2.25	15.48	2.91	26.09
17.000	6.744	4.74	32.66	5.57	50.00	36.000	14.251	2.13	14.66	2.84	25.48
18.000	7.141	4.67	30.85	5.27	47.33	37.000	14.678	2.01	13.84	2.78	24.91
19.000	7.537	4.26	29.37	5.01	44.96	38.000	15.075	1.89	13.03	2.72	24.36
20.000	7.934	4.08	28.11	4.77	42.85	39.000	15.471	1.77	12.23	2.66	23.85
21.000	8.331	3.92	27.03	4.56	40.94	40.000	15.868	1.66	11.45	2.60	23.36

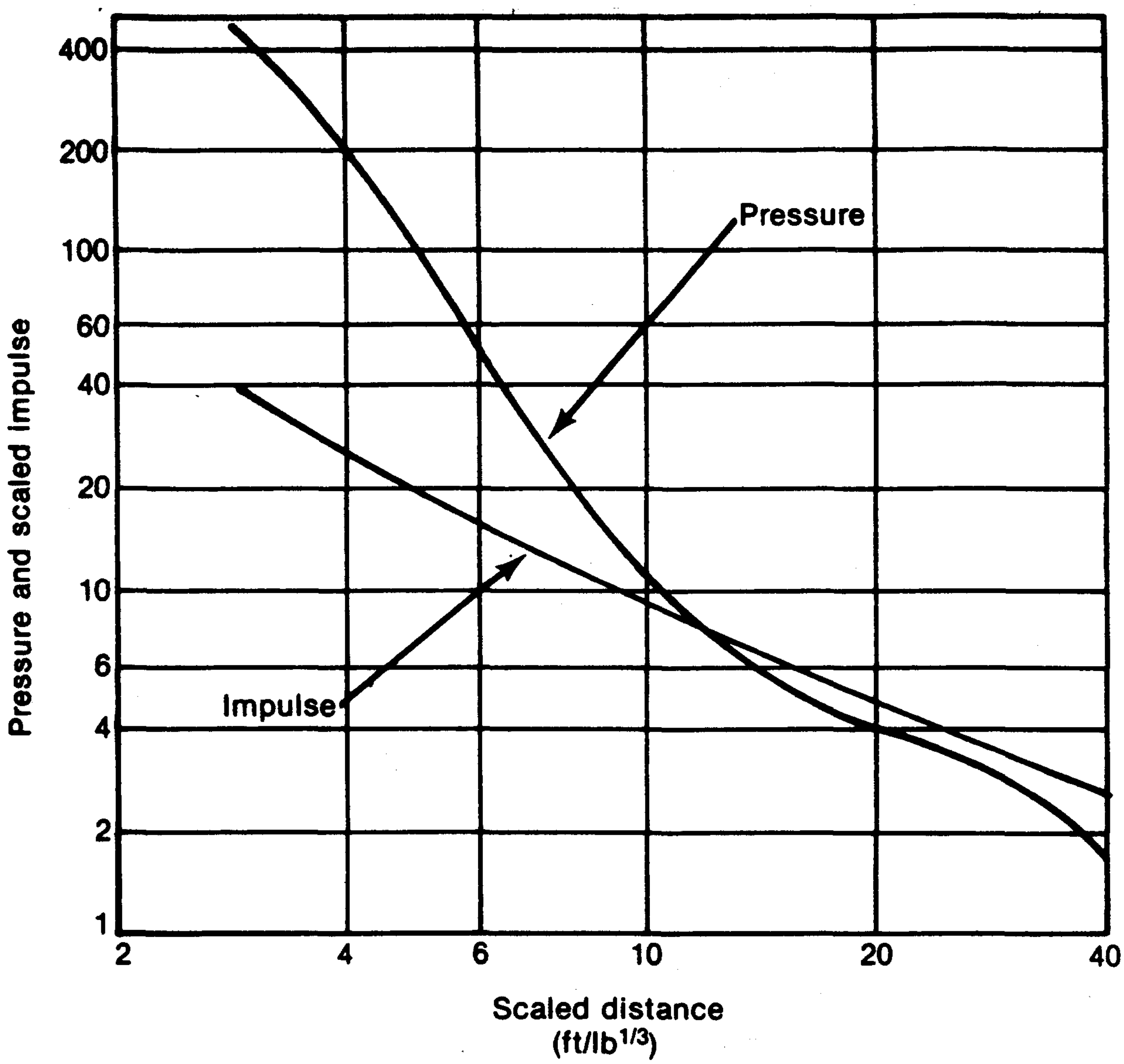


Figure 72. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for Octol 75/25 in Orthorhombic Configuration, L/D=0.7:1

Table 25. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse Values for Octol 75/25 in Truncated Prism (Hopper), L/D = 2:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	524.05	3613.31	41.30	370.64	22.000	8.727	3.38	23.28	3.10	27.81
4.000	1.587	302.38	2084.93	31.79	285.31	23.000	9.124	3.20	22.06	2.87	25.79
5.000	1.983	150.14	1035.19	25.20	226.17	24.000	9.521	3.04	20.96	2.67	23.98
6.000	2.380	78.81	543.41	20.47	183.73	25.000	9.917	2.89	19.93	2.49	22.35
7.000	2.777	45.52	313.84	16.97	152.27	26.000	10.314	2.75	18.96	2.33	20.07
8.000	3.174	28.85	198.91	14.30	128.30	27.000	10.711	2.62	18.04	2.18	19.54
9.000	3.570	19.81	136.59	12.21	109.60	28.000	11.108	2.49	17.16	2.04	18.33
10.000	3.967	14.54	100.22	10.56	94.73	29.000	11.504	2.36	16.30	1.92	17.23
11.000	4.364	11.26	77.61	9.22	82.70	30.000	11.901	2.24	15.48	1.81	16.22
12.000	4.760	9.10	62.77	8.12	72.82	31.000	12.298	2.13	14.67	1.70	15.29
13.000	5.157	7.63	52.58	7.20	64.62	32.000	12.694	2.01	13.88	1.61	14.45
14.000	5.554	6.57	45.31	6.43	57.72	33.000	13.091	1.90	13.11	1.52	13.67
15.000	5.950	5.79	39.93	5.78	51.87	34.000	13.488	1.79	12.36	1.44	12.94
16.000	6.347	5.20	35.84	5.22	46.87	35.000	13.884	1.69	11.63	1.37	12.28
17.000	6.744	4.73	32.64	4.74	42.55	36.000	14.281	1.58	10.92	1.30	11.66
18.000	7.141	4.36	30.06	4.32	38.79	37.000	14.678	1.48	10.23	1.24	11.09
19.000	7.537	4.05	27.95	3.96	35.51	38.000	15.075	1.39	9.56	1.18	10.56
20.000	7.934	3.79	26.16	3.64	32.63	39.000	15.471	1.29	8.92	1.12	10.06
21.000	8.331	3.57	24.63	3.35	30.08	40.000	15.868	1.20	8.29	1.07	9.60

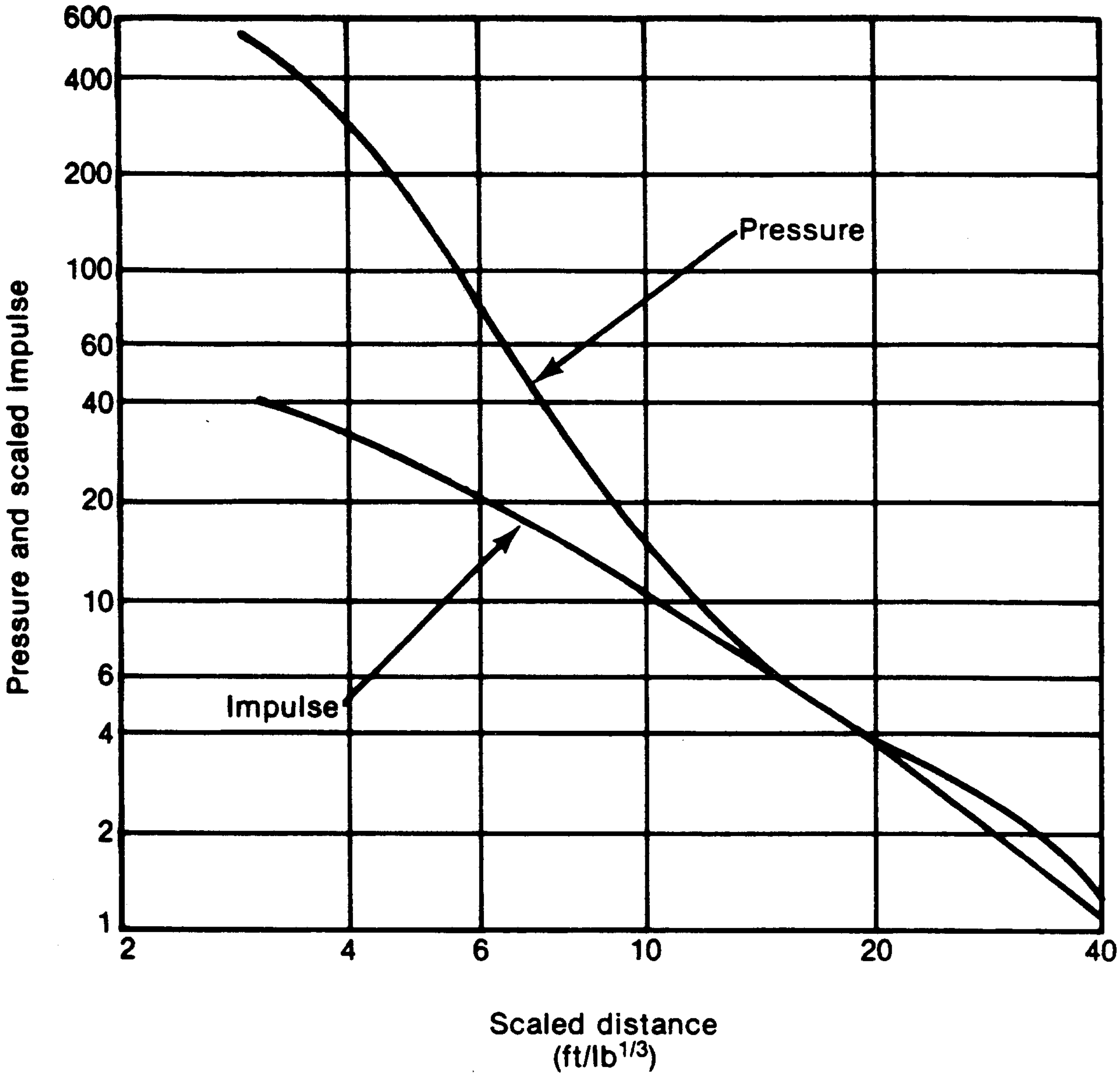


Figure 73. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for Octol 75/25 in Truncated Prism (Hopper). L/D = 2:1.

PBXC-203[15]

OBJECTIVE

The objective of these tests was to determine the maximum output from the detonation of PBXC-203 explosive in terms of peak pressure and positive impulse relative to TNT. Data are required for the design of barricades and blast walls and to determine if the various configurations tested scaled as a function of the charge weight.

MATERIALS

PBXC-203 is a free-flowing, granular molding powder formulated with a nominal composition by weight of 91% RDX and 9% ethylenevinyl acetate copolymer (EVA). The pressed density of PBXC-203 is 1.6+/-0.5 g/cm^3. PBXC-203 was received in both bulk and extruded rod forms.

TEST SETUP

Airblast output was evaluated in both bulk and extruded rod in cylindrical configurations using different diameters and charge weights. Physical characteristics of the test items are as follows:

(1) A cylindrical fiberboard container using bulk material with charge weights of 5.2 and 10.43 kg (11.5 and 23.0 lb). The L/D ratio was 1.8:1

(2) Single, double, and triple extruded rods in varying lengths and charge weights of 1.4, 2.8, and 5.6 kg (3.08, 6.16, and 12.32 lb) were tested.

Each bulk cylindrical container test was initiated by a M6 blasting cap and a conical-shaped Composition C4 booster charge varying in weight between 2 and 8% of the total charge weight with a L/D ratio of 1:4. The extruded rods were initiated in a similar manner but the L/D ratio was 1:2.

INSTRUMENTATION

Twelve side-on piezoelectric pressure transducers were flush mounted to the ground surface in a 90-degree array. Radial distances of 1.86, 2.74, 4.13, 6.19, 12.38, and 27.5 m (6.1, 8.98, 13.54, 20.3, 40.6, and 90.2 ft) were kept constant for each test configuration.

RESULTS

Test results of the combined bulk cylindrical tests with a L/D ratio of 1.8:1 are given in Table 26 and Figure 74. The combined results of the single, double and triple extruded rod with an effective L/D ratio of 20:1 are given in Table 27 and Figure 75. The results for both series of tests were combined for statisitical valididy and all of the reported values are within one standard deviation of the mean.

DISCUSSION

The pressure values for the cylindrical bulk PBXC-203 with a L/D ratio of 1.8:1 were greater than expected at all scaled distances of the experiment. Pressure values were 1934, 1092, 514, 139, 37, and 15.2 kPa (280.5, 158.4, 74.6, 20.1, 5.3, and 2.2 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0,. 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 2.8, 3.0, 2.7, 2.1, 2.2, and 4.5 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were greater than expected at scaled distances equal to or less than 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$) and less than expected at a scaled distance of 15.87 m/kg$^{1/3}$ (40.0 ft/lb$^{1/3}$). The scaled positive impulse values were 284, 245, 168, 84, 48, and 14.4 kPa-ms/kg$^{1/3}$ (31.7, 27.3, 18.7, 9.4, 5.3, and 1.6 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$) respectively. These values equate to 2.3, 2.7, 2.1, 1.4, 1.5, and 0.8 times equal amounts of TNT at the same scaled distances, respectively.

Pressure values for the combined values of the extruded rod tests were greater than expected at all scaled distances of the experiment. Pressure values were 1886, 117, 613, 185, 48, and 14.8 kPa (273.5, 170.7, 88.9, 26.8, 6.9, and 2.14 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 2.7, 3.4, 3.4. 3.1, 3.3, and 3.9 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were greater than expected at all scaled distances of the experiment. The combined scaled positive impulse values were 294, 238, 202, 136, 53, and 22.4 kPa-ms/kg$^{1/3}$ (32.8, 26.5, 22.5, 15.2, 5.9, and 2.5 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59,2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These values equate to 2.5, 2.5, 3.0, 3.0, 1.8, and 1.5 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) PBXC-203, when detonated, can generate peak pressure and positive impulse values which are greater than those produced by equal amounts of TNT.

(2) The blast output from PBXC-203 is dependant upon the configuration from which it detonates.

(3) To within experimental limits, blast pressure and scaled positive impulse scale as a cube-root function of the charge weight.

Table 26. Summary of Results for Hemispherical Surface Bursts, Peak Pressure and Scaled Positive Impulse Values for PBXC-203 in Cylindrical Configuration, L/D = 1.8:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	280.49	1934.00	31.67	284.19	22.000	8.727	4.12	28.44	4.59	41.34
4.000	1.587	158.35	1091.34	27.25	244.52	23.000	9.124	3.92	27.02	4.42	39.71
5.000	1.983	91.21	628.92	20.84	187.03	24.000	9.521	3.74	25.77	4.25	38.17
6.000	2.280	56.51	389.66	16.12	144.65	25.000	9.917	3.58	24.66	4.08	36.62
7.000	2.777	37.69	259.89	12.96	116.29	26.000	10.314	3.43	23.67	3.91	35.07
8.000	3.174	26.80	184.77	10.84	97.39	27.000	10.711	3.30	22.77	3.73	33.50
9.000	3.570	20.09	138.51	9.39	84.24	28.000	11.108	3.18	21.96	3.56	31.93
10.000	3.967	15.73	108.44	8.36	75.01	29.000	11.304	3.08	21.21	3.38	30.36
11.000	4.344	12.76	87.97	7.61	68.27	30.000	11.901	2.97	20.51	3.21	28.80
12.000	4.760	10.66	73.49	7.04	60.20	31.000	12.298	2.88	19.87	3.04	27.24
13.000	5.157	9.12	62.89	6.60	59.27	32.000	12.494	2.79	19.26	2.86	25.71
14.000	5.554	7.96	54.91	6.25	56.12	33.000	13.091	2.71	18.69	2.70	24.20
15.000	5.950	7.07	48.76	5.96	53.53	34.000	13.488	2.63	18.16	2.53	22.72
16.000	6.347	6.37	43.90	5.72	51.31	35.000	13.884	2.56	17.64	2.37	21.27
17.000	6.744	5.80	40.00	5.50	49.35	36.000	14.281	2.49	17.15	2.21	19.87
18.000	7.141	5.34	36.82	5.30	47.57	37.000	14.678	2.42	16.68	2.06	18.51
19.000	7.537	4.96	34.18	5.12	45.91	38.000	15.075	2.35	16.23	1.92	17.21
20.000	7.934	4.63	31.96	4.94	44.32	39.000	15.471	2.29	15.80	1.78	15.96
21.000	8.331	4.36	30.07	4.77	42.77	40.000	15.868	2.23	15.37	1.64	14.76

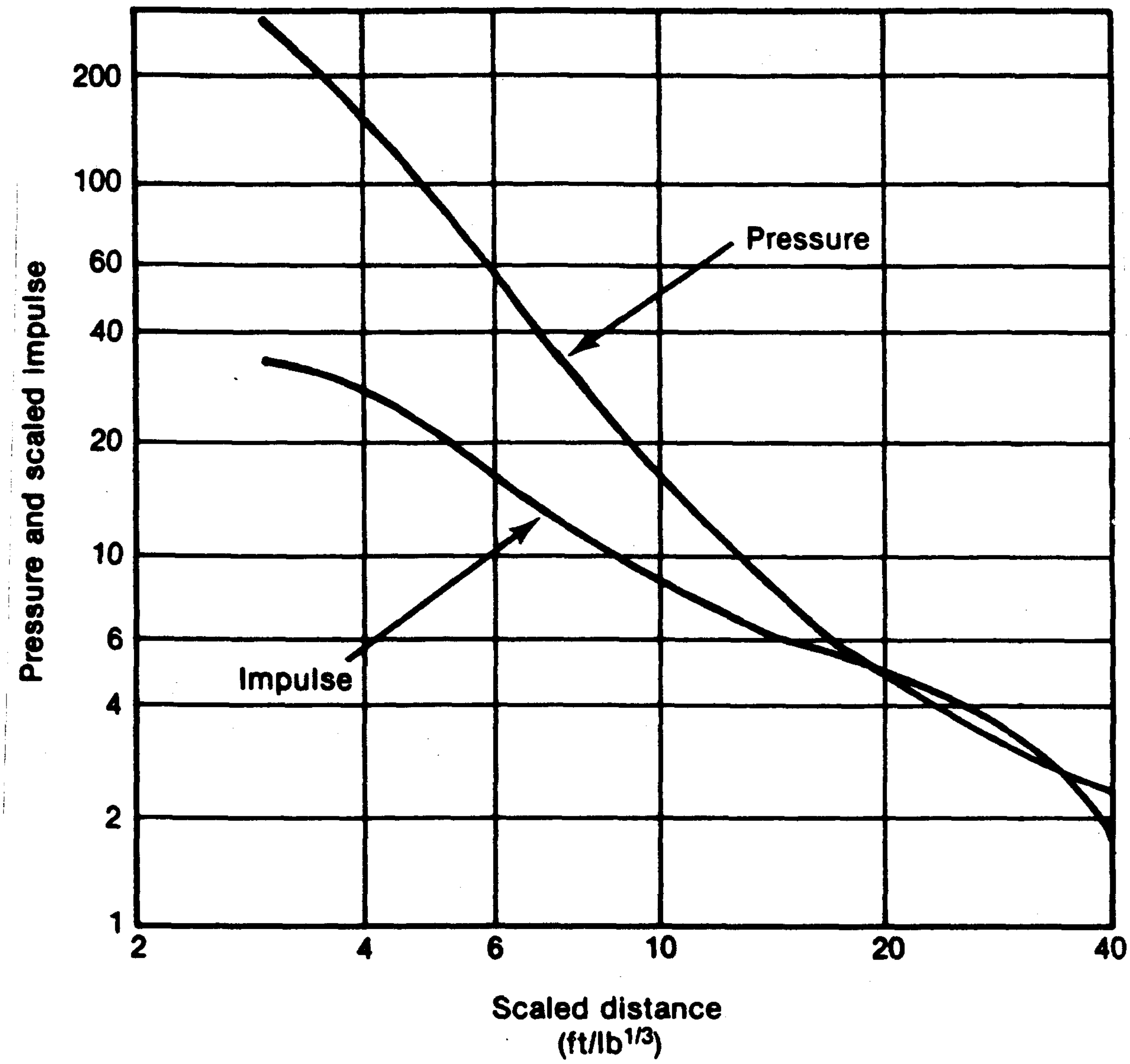


Figure 74. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for PBXC-203 in Cylindrical Configuration, L/D = 1.8:1.

Table 27. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse Values for PBXC-203 Extruded Rod L/D = 20:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	237.49	1885.68	32.80	294.32	22.000	8.727	5.03	34.68	4.33	38.84
4.000	1.587	170.74	1177.25	26.54	238.21	23.000	9.124	4.71	32.49	4.06	36.41
5.000	1.983	106.10	731.25	23.49	210.83	24.000	9.521	4.43	30.55	3.82	34.30
6.000	2.380	49.42	478.68	21.14	189.73	25.000	9.917	4.18	28.83	3.62	32.46
7.000	2.777	48.11	331.74	19.01	170.56	26.000	10.314	3.96	27.28	3.44	30.86
8.000	3.174	35.11	242.07	17.02	152.71	27.000	10.711	3.75	25.88	3.28	29.46
9.000	3.570	26.76	184.52	15.19	136.27	28.000	11.108	3.57	24.60	3.15	28.25
10.000	3.967	21.15	145.86	13.53	121.42	29.000	11.504	3.40	23.43	3.03	27.20
11.000	4.364	17.23	118.83	12.04	108.21	30.000	11.901	3.24	22.35	2.93	26.30
12.000	4.760	14.40	99.26	10.76	96.59	31.000	12.298	3.10	21.36	2.84	25.53
13.000	5.157	12.28	84.66	9.63	86.45	32.000	12.694	2.96	20.43	2.77	24.87
14.000	5.554	10.66	73.48	8.65	77.64	33.000	13.091	2.84	19.57	2.71	24.31
15.000	5.950	9.39	64.73	7.80	70.02	34.000	13.488	2.72	18.76	2.66	23.86
16.000	6.347	8.37	57.73	7.07	63.43	35.000	13.884	2.61	17.99	2.62	23.49
17.000	6.744	7.55	52.04	6.43	57.73	36.000	14.281	2.51	17.28	2.59	23.21
18.000	7.141	6.87	47.34	5.88	52.80	37.000	14.478	2.41	16.60	2.56	23.00
19.000	7.537	6.29	43.39	5.41	48.53	38.000	15.075	2.31	15.95	2.55	22.80
20.000	7.934	5.81	40.05	5.00	44.84	39.000	15.471	2.22	15.34	2.54	22.80
21.000	8.331	5.39	37.17	4.64	41.63	40.000	15.848	2.14	14.75	2.54	22.80

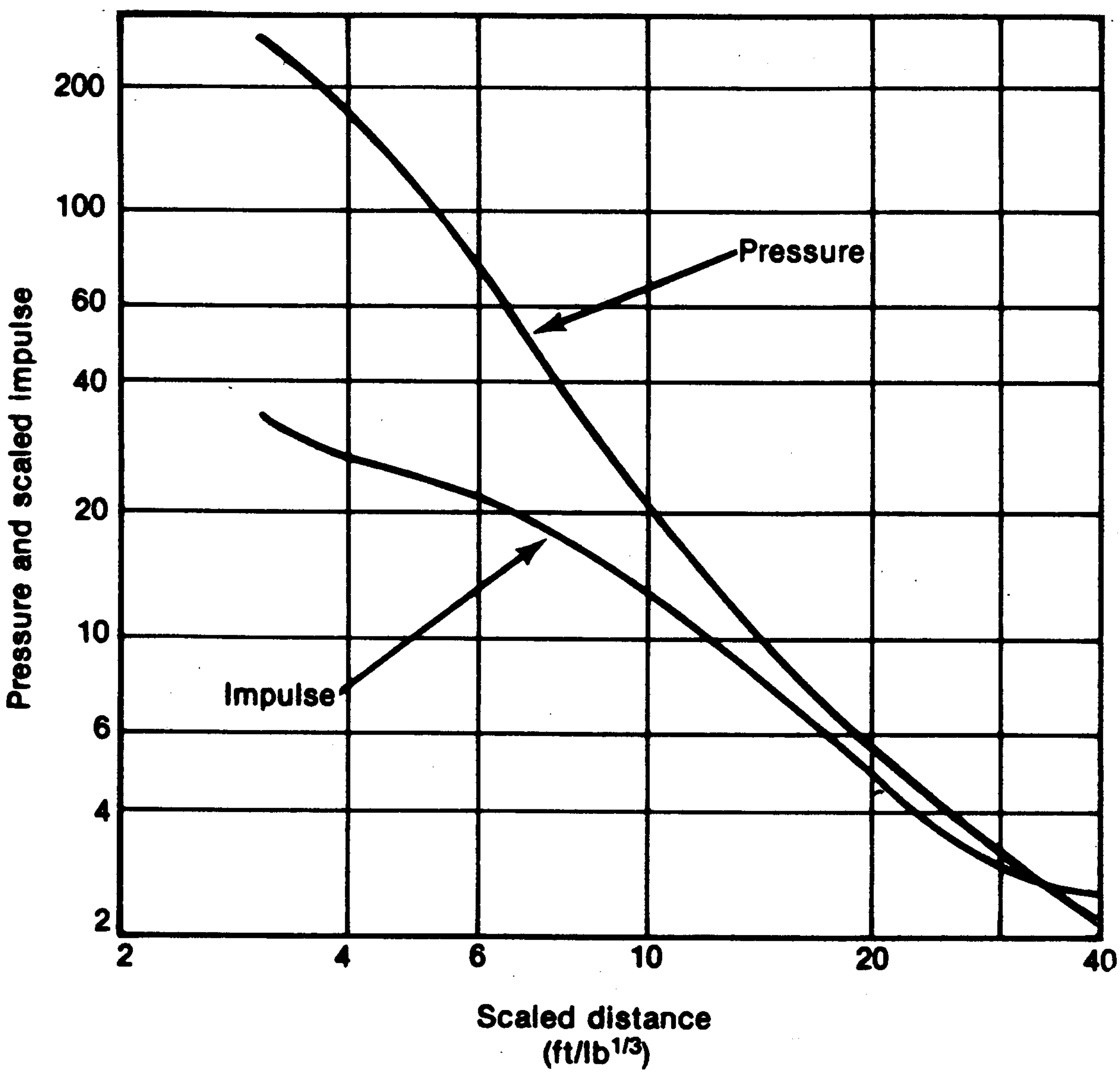


Figure 75. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for PBXC-203 Extruded Rod, L/D = 20:1.

PBXN-106 (PRECOAT) AND PBXW-109 (PRECOAT) EXPLOSIVES

OBJECTIVE

The objective of this work was to determine the maximum blast output from the detonation of PBXN-106 (Precoat) and PBXW-109 (Precoat) in various configurations. The measured pressure and impulse values were compared with known characteristics of a hemispherical surface burst of TNT in order to determine the equivalency of PBXN-106 (Precoat) and PBXW-109 (Precoat) in relation to TNT.

MATERIALS

The test material was PBXN-106 (Precoat) and PBXW-109 (Precoat). The PBX (plastic bonded explosives) were received from the Naval Weapons Station, Yorktown, Virginia, 23691, in standard shipping boxes. The physical characteristics of the PBX was the molding powder form in which it is packaged for shipment to the user for additional processing. The PBX (plastic bonded explosive), are prepared by a slurry technique: powdered explosive (RDX) and water are agitated in a container. A plasticizer is dissolved in suitible solvent and added to the slurry. The solvent is removed causing the plastic phase to precipitate out onto the explosive as a coating. Finally, water is removed by filtering and drying operations, leaving a molding powder which is packed for shipment to the user for additional processing. The chemical constituents of the explosives are: PBXN-106 (Precoat) RDX (CL1)/RDX (CL5)/Nitroplasticizer (50/50 mix Dintro-proplacetal/Dinitro-propyl formal) in percentages by weight 76/19/5%, respectively, and PBXW-109 (Precoat) RDX (CL1)/RDX (CL5)/Dioctyl Adipate in percentages by weight 85/10/5%, respectively.

TEST SETUP

Airblast output was evaluated for weights and configurations of PBXN-106 (Precoat) and PBXW-109 (Precoat) representative of shipping and in-plant situations. Physical characteristics of the test items are as follows:

(1) An orthorhombic container was used to simulate the nutsche container (transfer box) with a dimensional scaling factor of 0.585 and a charge weight 90.72 kg (200 lb). The container was constructed from plywood with a lenght of 71.12 cm (28.0 inches), a width of 44.45 cm (17.5 inches), and a height of 30.99 cm (12.2 inches).

(2) An orthorhombic container was used to simulate the nutsche container (transfer box) with a dimensional scaling factor of 0.464 and a charge weight 45.36 kg (100 lb). The container was constructed from plywood with a lenght of 56.39 cm (22.2 inches), a width of 35.56 cm (14.0 inches), and a height of 24.64 cm (9.7 inches).

PBXN-106 (PRECOAT) AND PBXW-109 (PRECOAT) EXPLOSIVES

OBJECTIVE

The objective of this work was to determine the maximum blast output from the detonation of PBXN-106 (Precoat) and PBXW-109 (Precoat) in various configurations. The measured pressure and impulse values were compared with known characteristics of a hemispherical surface burst of TNT in order to determine the equivalency of PBXN-106 (Precoat) and PBXW-109 (Precoat) in relation to TNT.

MATERIALS

The test material was PBXN-106 (Precoat) and PBXW-109 (Precoat). The PBX (plastic bonded explosives) were received from the Naval Weapons Station, Yorktown, Virginia, 23691, in standard shipping boxes. The physical characteristics of the PBX was the molding powder form in which it is packaged for shipment to the user for additional processing. The PBX (plastic bonded explosive), are prepared by a slurry technique: powdered explosive (RDX) and water are agitated in a container. A plasticizer is dissolved in suitible solvent and added to the slurry. The solvent is removed causing the plastic phase to precipitate out onto the explosive as a coating. Finally, water is removed by filtering and drying operations, leaving a molding powder which is packed for shipment to the user for additional processing. The chemical constituents of the explosives are: PBXN-106 (Precoat) RDX (CL1)/RDX (CL5)/Nitroplasticizer (50/50 mix Dintro-proplacetal/Dinitro-propyl formal) in percentages by weight 76/19/5%, respectively, and PBXW-109 (Precoat) RDX (CL1)/RDX (CL5)/Dioctyl Adipate in percentages by weight 85/10/5%, respectively.

TEST SETUP

Airblast output was evaluated for weights and configurations of PBXN-106 (Precoat) and PBXW-109 (Precoat) representative of shipping and in-plant situations. Physical characteristics of the test items are as follows:

(1) An orthorhombic container was used to simulate the nutsche container (transfer box) with a dimensional scaling factor of 0.585 and a charge weight 90.72 kg (200 lb). The container was constructed from plywood with a lenght of 71.12 cm (28.0 inches), a width of 44.45 cm (17.5 inches), and a height of 30.99 cm (12.2 inches).

(2) An orthorhombic container was used to simulate the nutsche container (transfer box) with a dimensional scaling factor of 0.464 and a charge weight 45.36 kg (100 lb). The container was constructed from plywood with a lenght of 56.39 cm (22.2 inches), a width of 35.56 cm (14.0 inches), and a height of 24.64 cm (9.7 inches).

scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 5.0, 5.2, 4.0, 1.4, 0.9, and 0.9 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were greater than expected at all scaled distances of the experiment. The scaled positive impulse values were 336.1, 266.9, 193.0, 103.5, 43.2, and 19.7 kPa-ms/kg$^{1/3}$ (37.45, 29.74, 21.51, 11.53, 4.81, and 2.20 psi-ms/ft$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 3.0, 3.1, 2.7, 2.0, 1.2, and 1.2 times equal amounts of TNT at the same scaled distances, respectively.

Pressure values for PBXN-106 (Precoat) 90.72 kg (200 lb) in a simulated nutsche container were greater than expected at all scaled distances of the experiment. The pressure values were 2950.9, 1683.9, 705.2, 125.7, 26.4, and 8.9 kPa (427.97, 244.22, 102.28, 18.23, 3.83, and 1.29 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 4.9, 5.4, 4.1, 1.8, 1.2, and 1.2 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were greater than expected at scaled distances equal to or less than 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$) and less than expected at scaled distances equal to or greater than 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$). The scaled positive impulse values were 306.4, 289.0, 152.4, 71.3, 34.2, and 13.3 kPa-ms/kg$^{1/3}$ (34.14, 32.20, 16.98, 7.95, 3.81, and 1.48 psi-ms/ft$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 2.6, 3.6, 1.8, 1.1, 0.9, and 0.7 times equal amounts of TNT at the same scaled distances, respectively.

Pressure values for PBXW-109 (Precoat) 27.22 kg (60 lb) in full scale shipping/storage container were greater than expected at scaled distances equal to or less than 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$), less than expected at a scaled distance of 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$) and greater than expected at a scaled distance of 15.87 m/kg$^{1/3}$. The pressure values were 2580.7, 1275.4, 552.4, 91.8, 21.4, and 9.1 kPa (374.29, 184.98, 80.11, 13.31, 3.11, and 1.32 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 4.1, 3.7, 2.9, 1.2, 0.8, and 1.2 times equal amounts of TNT at the same scaled distance, respectively. The scaled positive impulse values were greater than expected at scaled distances equal to or less than 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$) and less than expected at scaled distances equal to or greater than 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$) and greater than expected at a scaled distance of 15.87 m/kg$^{1/3}$ (40.0 ft/lb$^{1/3}$). The scaled positive impulse values were 259.2, 225.2, 154.8, 77.4, 35.8, and 18.8 kPa-ms/kg$^{1/3}$ (28.88, 25.09, 17.25, 8.63, 3.99, and 2.09 psi-ms/ft$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 2.0, 2.3, 1.9, 1.2, 0.9, and 1.1 times equal amounts of TNT at the same scaled distances, respectively.

Pressure values for PBXW-109 (Precoat) 45.36 kg (100 lb) in a simulated nutsche container were greater than expected at scaled distances equal to or less than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$), less than expected at a scaled distance of 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$) and greater than expected at a scaled distance of 15.87 $m/kg^{1/3}$. The pressure values were 2910.2, 1604.6, 703.6, 104.0, 22.1, and 8.4 kPa (422.08, 232.72, 102.05, 15.08, 3.21, and 1.22 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 4.8, 5.1, 4.1, 1.4, 0.8, and 1.1 times equal amounts of TNT at the same scaled distance, respectively. The scaled positive impulse values were greater than expected at all scaled distances of the experiment. The scaled positive impulse values were 286.0, 245.9, 151.2, 84.3, 43.6, and 18.5 kPa-$ms/kg^{1/3}$ (31.87, 27.40, 16.85, 9.39, 4.86, and 2.06 psi-$ms/ft^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 2.3, 2.8, 1.8, 1.3, 1.1, and 1.1 times equal amounts of TNT at the same scaled distances, respectively.

Pressure values for PBXW-109 (Precoat) 90.72 kg (200 lb) in a simulated nutsche container were greater than expected at all scaled distances of the experiment. The pressure values were 2798.7, 1557.9, 587.2, 96.1, 22.8, and 8.5 kPa (405.91, 225.94, 85.17, 13.94, 3.60, and 1.23 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 4.5, 4.9, 3.2, 1.2, 1.0, and 1.1 times equal amounts of TNT at the same scaled distance, respectively. The scaled positive impulse values were greater than expected at scaled distances equal to or less than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$) and less than expected at scaled distances equal to or greater than 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$) and greater than expected at a scaled distance of 15.87 $m/kg^{1/3}$ (40.0 $ft/lb^{1/3}$). The scaled positive impulse values were 258.4, 195.7, 147.2, 71.7, 32.2, and 18.8 kPa-$ms/kg^{1/3}$ (28.79, 21.81, 16.40, 7.99, 3.59, and 2.10 psi-$ms/ft^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 2.0, 1.9, 1.7, 1.0, 0.8, and 1.1 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) The blast output from PBXN-106 (Precoat) and PBXW-109 (Precoat) explosives are dependent upon the configuration from which they detonate.

(2) The explosive yield in comparison to hemispherical TNT was much greater for the close-in scaled distances equal to or less tha 2.14 $m/kg^{1/3}$ (5.4 $ft/lb^{1/3}$).

(3) To within experimental limits, blast pressure and impulse scale as a cube-root function of the charge weight for both the PBXN-106 (Precoat) and the PBXW-109 (Precoat) explosives.

Table 28. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse values for PBXN-106 (Precoat), 27.22 kg

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse psi · ms / $lb^{1/3}$	Scaled Impulse kPa · ms / $kg^{1/3}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse psi · ms / $lb^{1/3}$	Scaled Impulse kPa · ms / $kg^{1/3}$
3.000	1.190	397.45	2740.22	34.91	313.33	22.000	8.727	2.88	19.85	2.84	25.45
4.000	1.587	233.60	1610.64	24.30	218.06	23.000	9.124	2.77	19.13	2.68	24.07
5.000	1.983	114.69	790.76	18.34	164.62	24.000	9.521	2.68	18.47	2.54	22.81
6.000	2.380	59.28	408.73	14.58	130.83	25.000	9.917	2.59	17.85	2.41	21.67
7.000	2.777	33.81	233.09	12.01	107.74	26.000	10.314	2.50	17.27	2.30	20.62
8.000	3.174	21.25	146.53	10.15	91.05	27.000	10.711	2.42	16.70	2.19	19.67
9.000	3.570	14.54	100.26	8.75	78.50	28.000	11.108	2.34	16.13	2.09	18.78
10.000	3.967	10.67	73.60	7.66	68.74	29.000	11.504	2.26	15.58	2.00	17.97
11.000	4.364	8.30	57.21	6.79	60.96	30.000	11.901	2.18	15.02	1.92	17.22
12.000	4.760	6.76	46.59	6.09	54.63	31.000	12.298	2.10	14.45	1.84	16.52
13.000	5.157	5.71	39.37	5.50	49.39	32.000	12.694	2.01	13.89	1.77	15.88
14.000	5.554	4.97	34.30	5.01	44.99	33.000	13.091	1.93	13.31	1.70	15.27
15.000	5.950	4.44	30.60	4.60	41.24	34.000	13.488	1.85	12.74	1.64	14.71
16.000	6.347	4.04	27.84	4.24	38.02	35.000	13.884	1.76	12.16	1.58	14.18
17.000	6.744	3.73	25.71	3.93	35.22	36.000	14.281	1.68	11.57	1.53	13.69
18.000	7.141	3.49	24.05	3.61	32.78	37.000	14.678	1.59	10.99	1.47	13.22
19.000	7.537	3.29	22.70	3.41	30.62	38.000	15.075	1.51	10.41	1.42	12.78
20.000	7.934	3.13	21.60	3.20	28.70	39.000	15.471	1.43	9.84	1.38	12.37
21.000	8.331	3.00	20.66	3.01	26.95	40.000	15.868	1.34	9.27	1.34	11.98

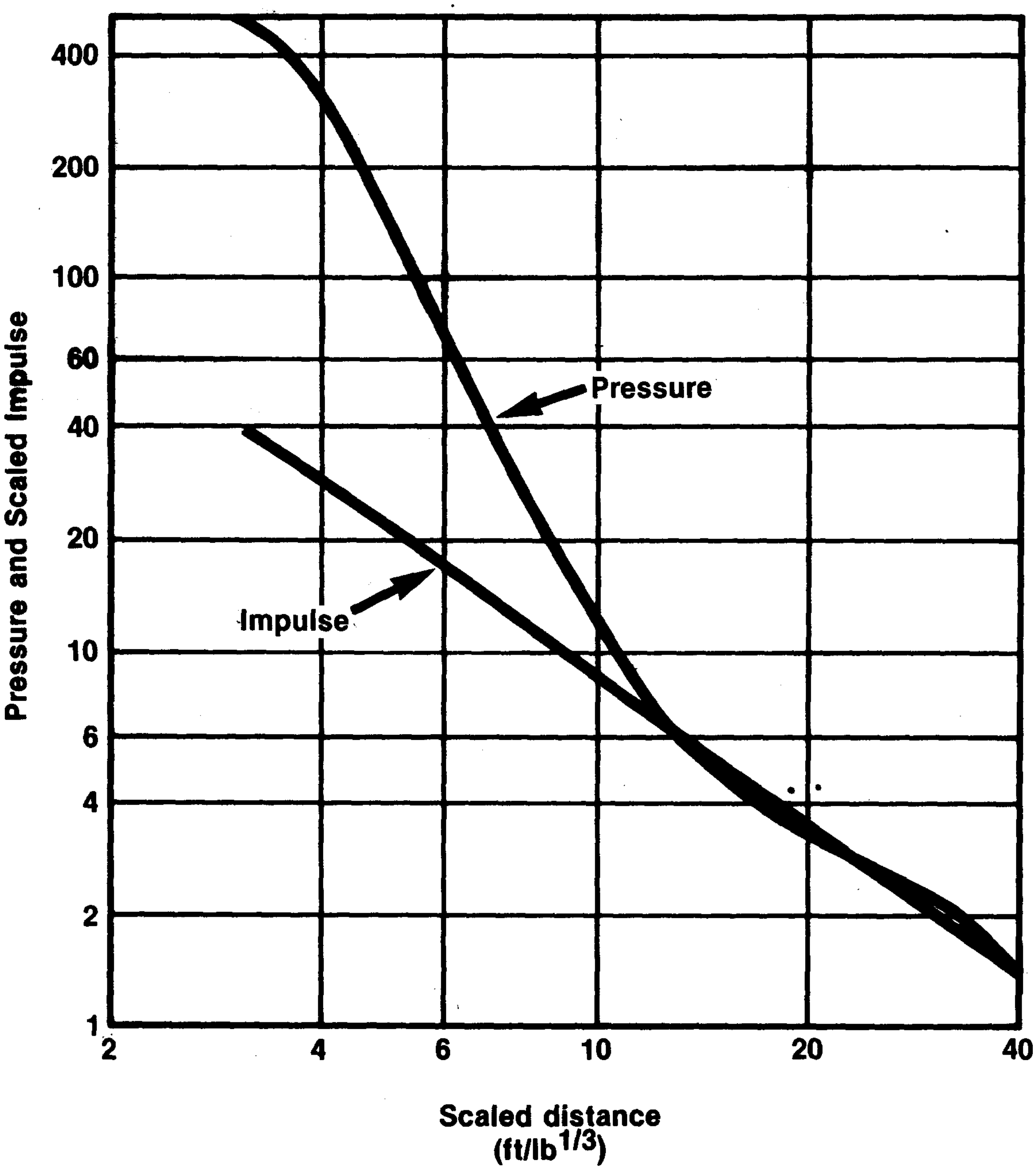


Figure 76. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for PBXN-106 (Precoat) for 27.22 kg Orthorhombic Shipping Container.

Table 29. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse values for PBXN-106 (Precoat), 45.36 kg

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	427.10	2944.88	37.49	336.41	22.000	8.727	2.72	18.72	3.77	33.82
4.000	1.587	276.29	1905.03	29.61	265.74	23.000	9.124	2.61	18.02	3.59	32.23
5.000	1.983	134.96	930.57	23.58	211.63	24.000	9.521	2.52	17.37	3.44	30.83
6.000	2.380	67.54	465.69	19.15	171.84	25.000	9.917	2.43	16.76	3.29	29.57
7.000	2.777	37.13	256.03	15.87	142.42	26.000	10.314	2.35	16.17	3.17	28.43
8.000	3.174	22.58	155.67	13.40	120.29	27.000	10.711	2.26	15.60	3.06	27.42
9.000	3.570	15.02	103.57	11.51	103.30	28.000	11.108	2.18	15.02	2.95	26.50
10.000	3.967	10.78	74.32	10.03	90.01	29.000	11.504	2.10	14.45	2.86	25.66
11.000	4.364	8.23	56.75	8.85	79.44	30.000	11.901	2.01	13.86	2.78	24.91
12.000	4.760	6.61	45.58	7.90	70.96	31.000	12.298	1.93	13.28	2.70	24.22
13.000	5.157	5.53	38.13	7.12	63.91	32.000	12.694	1.84	12.68	2.63	23.59
14.000	5.554	4.78	32.96	6.47	58.16	33.000	13.091	1.75	12.08	2.56	23.02
15.000	5.950	4.24	29.25	5.93	53.23	34.000	13.488	1.66	11.47	2.51	22.49
16.000	6.347	3.84	26.50	5.47	49.11	35.000	13.884	1.58	10.86	2.45	22.01
17.000	6.744	3.54	24.41	5.08	45.58	36.000	14.281	1.49	10.26	2.40	21.57
18.000	7.141	3.30	22.78	4.74	42.55	37.000	14.678	1.40	9.65	2.36	21.17
19.000	7.537	3.12	21.48	4.45	39.92	38.000	15.075	1.31	9.05	2.32	20.80
20.000	7.934	2.96	20.41	4.19	37.62	39.000	15.471	1.23	8.46	2.28	20.46
21.000	8.331	2.83	19.51	3.97	35.60	40.000	15.868	1.14	7.88	2.25	10.15

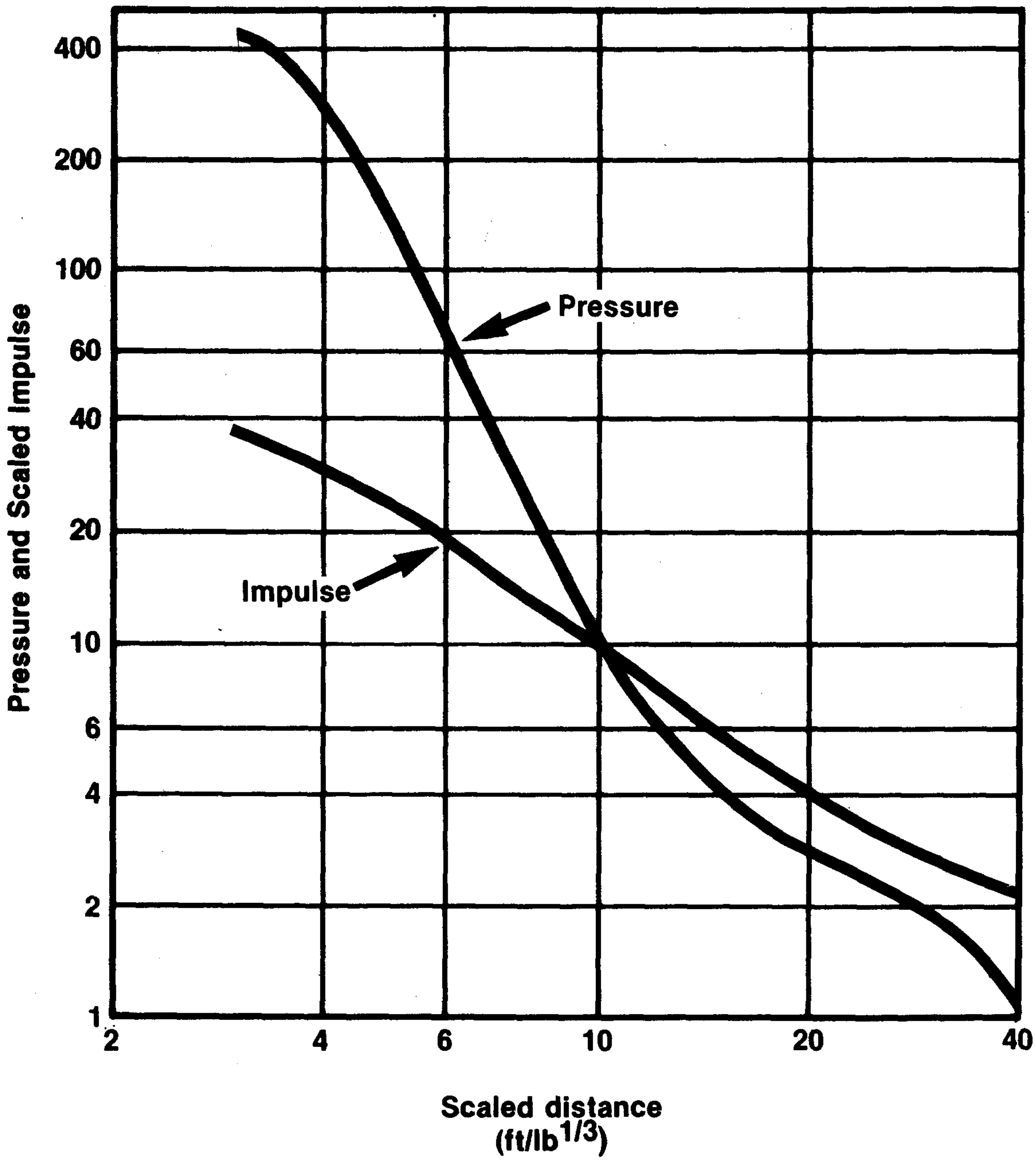


Figure 77. **Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for PBXN-106 (Precoat) for 45.36 kg Simulated Nutsche Container.**

Table 30. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse values for PBXN-106 (Precoat), 90.72 kg

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse psi • ms / $lb^{1/3}$	Scaled Impulse kPa • ms / $kg^{1/3}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse psi • ms / $lb^{1/3}$	Scaled Impulse kPa • ms / $kg^{1/3}$
3.000	1.190	427.72	2949.13	37.72	338.49	22.000	8.727	2.92	20.14	3.88	34.85
4.000	1.587	245.78	1694.67	27.16	243.77	23.000	9.124	2.77	19.08	3.69	33.13
5.000	1.983	126.52	872.34	21.06	188.98	24.000	9.521	2.63	18.14	3.52	31.56
6.000	2.380	68.82	474.53	17.10	153.46	25.000	9.917	2.51	17.30	3.36	30.12
7.000	2.777	40.82	281.42	14.34	128.73	26.000	10.314	2.40	16.53	3.21	28.86
8.000	3.174	26.31	181.42	12.32	110.54	27.000	10.711	2.29	15.82	3.07	27.59
9.000	3.570	18.23	123.70	10.77	96.64	28.000	11.108	2.20	15.15	2.95	26.47
10.000	3.967	13.42	92.50	9.55	85.69	29.000	11.504	2.11	14.52	2.83	25.43
11.000	4.364	10.37	71.52	8.56	76.86	30.000	11.901	2.02	13.93	2.73	24.46
12.000	4.760	8.35	57.59	7.76	69.60	31.000	12.298	1.94	13.35	2.63	23.47
13.000	5.157	6.95	47.93	7.08	63.52	32.000	12.694	1.86	12.80	2.53	22.73
14.000	5.554	5.94	40.99	6.50	58.37	33.000	13.091	1.78	12.27	2.45	21.94
15.000	5.950	5.20	35.84	6.01	53.95	34.000	13.488	1.70	11.75	2.36	21.21
16.000	6.347	4.63	31.91	5.59	50.12	35.000	13.884	1.63	11.25	2.29	20.52
17.000	6.744	4.18	28.85	5.21	46.77	36.000	14.281	1.56	10.76	2.21	19.87
18.000	7.141	3.83	26.40	4.88	43.82	37.000	14.678	1.49	10.27	2.15	19.26
19.000	7.537	3.54	24.40	4.54	41.20	38.000	15.075	1.42	9.80	2.08	18.66
20.000	7.934	3.30	22.74	4.33	38.86	39.000	15.471	1.36	9.35	2.02	18.14
21.000	8.331	3.10	21.34	4.10	36.75	40.000	15.868	1.29	8.90	1.96	17.62

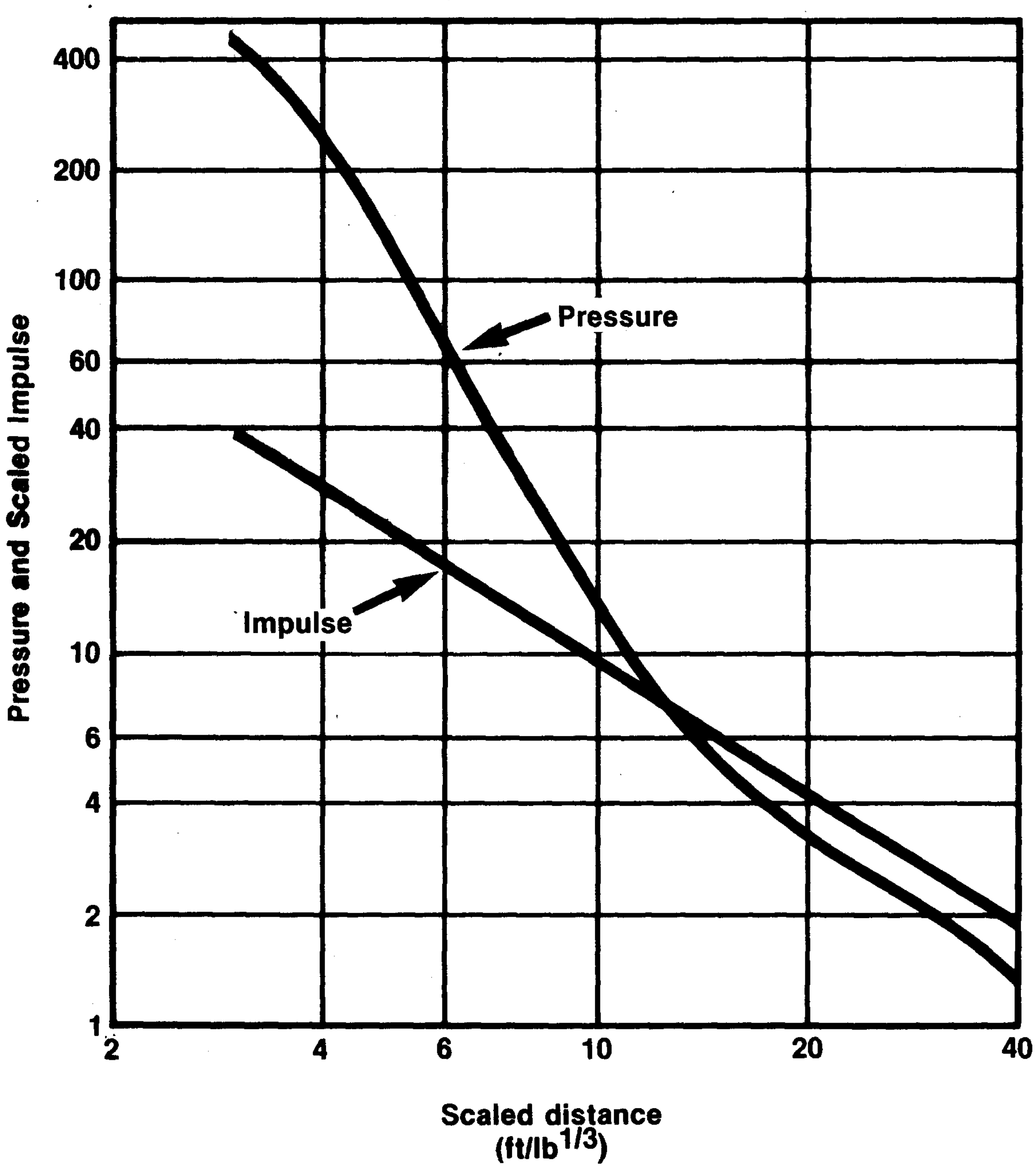


Figure 78. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for PBXN-106 (Precoat) for 90.72 kg Simulated Nutsche Container.

Table 31. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse values for PBXW-109 (Precoat), 27.22 kg

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	370.50	2554.59	28.88	259.17	22.000	8.727	2.54	17.53	3.34	30.32
4.000	1.587	214.53	1479.16	24.24	217.52	23.000	9.124	2.45	16.91	3.26	29.29
5.000	1.983	105.34.	726.29	19.01	170.56	24.000	9.521	2.37	16.35	3.16	28.35
6.000	2.380	54.54	376.07	15.01	134.68	25.000	9.917	2.30	15.84	3.06	27.49
7.000	2.777	31.12	214.55	12.15	109.06	26.000	10.314	2.23	15.37	2.97	26.69
8.000	3.174	19.54	134.70	10.11	90.76	27.000	10.711	2.16	14.92	2.89	25.94
9.000	3.570	13.33	91.91	8.63	77.44	28.000	11.108	2.10	14.48	2.81	25.94
10.000	3.967	9.75	67.21	7.52	67.53	29.000	11.504	2.04	14.05	2.74	24.58
11.000	4.364	7.54	52.02	6.68	59.97	30.000	11.901	1.98	13.67	2.67	23.95
12.000	4.760	6.11	42.16	6.03	54.08	31.000	12.298	1.91	13.19	2.60	23.35
13.000	5.157	5.14	35.47	5.50	49.40	32.000	12.694	1.85	12.76	2.54	22.78
14.000	5.554	4.46	30.76	5.08	45.61	33.000	13.091	1.79	12.32	2.48	22.22
15.000	5.950	3.96	27.34	4.74	42.50	34.000	13.488	1.72	11.88	2.42	21.69
16.000	6.347	3.59	24.78	4.45	39.96	35.000	13.884	1.66	11.43	2.36	21.17
17.000	6.744	3.31	27.82	4.20	37.69	36.000	14.281	1.59	10.98	2.30	20.66
18.000	7.141	3.09	21.29	3.99	35.81	37.000	14.678	1.59	10.52	2.25	20.17
19.000	7.537	2.91	20.07	3.81	34.17	38.000	15.075	1.46	10.06	2.19	19.69
20.000	7.934	2.77	19.07	3.65	32.73	39.000	15.471	1.39	9.60	2.14	19.22
21.000	8.331	2.65	18.24	3.51	31.46	40.000	15.868	1.33	9.15	2.09	18.76

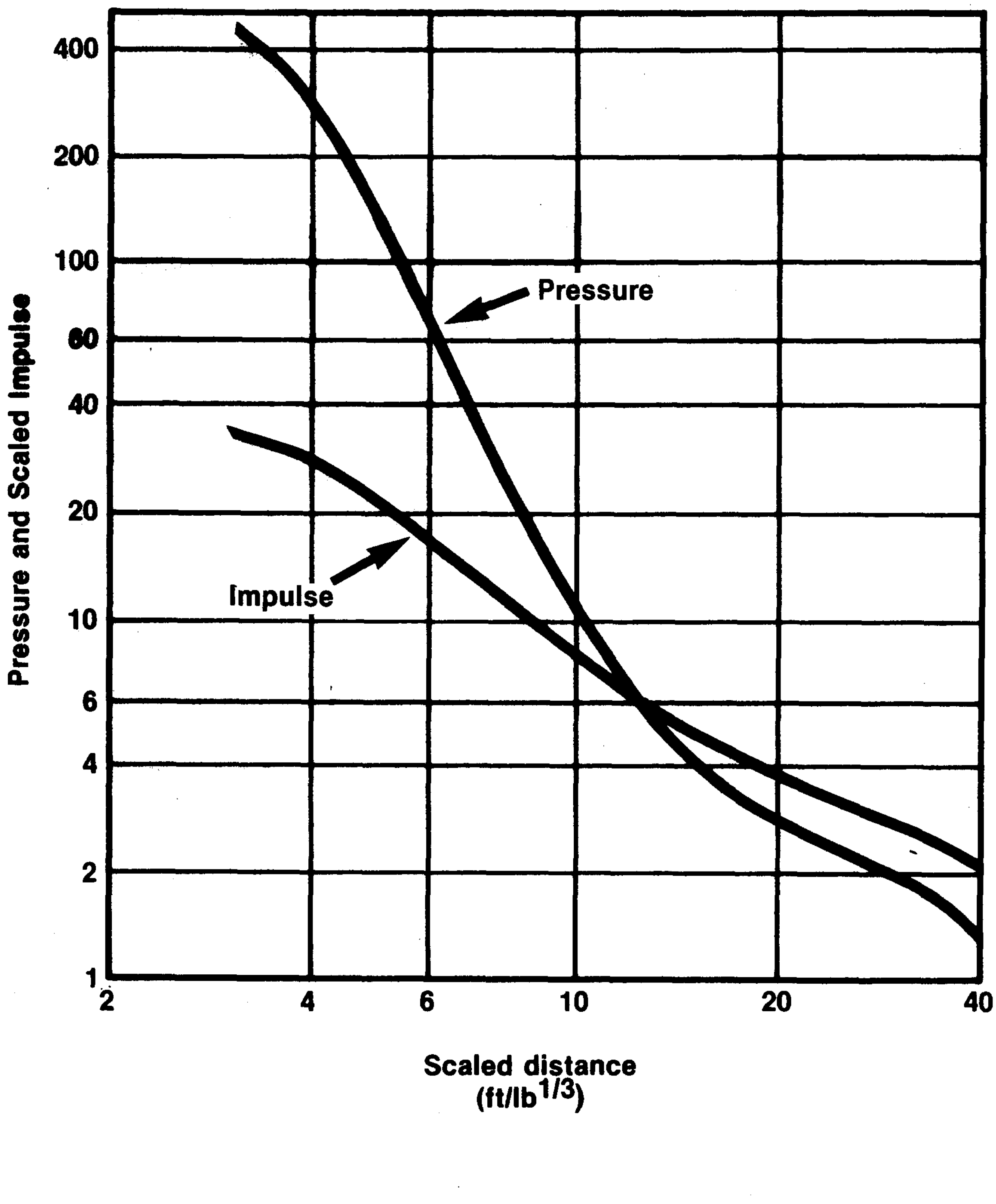


Figure 79. **Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for PBXW-109 (Precoat) for 27.22 kg Orthorhombic Shipping Container.**

Table 32. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse values for PBXW-109 (Precoat), 45.36 kg

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse psi · ms / $lb^{1/3}$	Scaled Impulse kPa · ms / $kg^{1/3}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse psi · ms / $lb^{1/3}$	Scaled Impulse kPa · ms / $kg^{1/3}$
3.000	1.190	421.27	2904.67	33.49	300.50	22.000	8.727	2.53	17.44	4.05	36.32
4.000	1.587	238.00	1640.99	24.68	221.48	23.000	9.124	2.42	16.66	3.86	34.64
5.000	1.983	117.41	809.51	19.46	174.80	24.000	9.521	2.32	15.98	3.69	33.11
6.000	2.380	61.32	422.78	16.05	144.07	25.000	9.917	2.23	15.35	3.53	31.71
7.000	2.777	35.19	242.65	13.63	122.34	26.000	10.314	2.14	14.78	3.39	30.42
8.000	3.174	22.14	152.66	11.83	106.18	27.000	10.711	2.07	14.25	3.26	29.23
9.000	3.570	15.08	104.01	10.44	93.71	28.000	11.108	1.99	13.74	3.13	28.12
10.000	3.967	10.98	75.71	9.34	83.81	29.000	11.504	1.92	13.25	3.02	27.09
11.000	4.364	8.44	58.19	8.44	75.75	30.000	11.901	1.85	12.78	2.91	26.14
12.000	4.760	6.78	46.76	7.70	69.07	31.000	12.298	1.79	12.32	2.81	25.24
13.000	5.157	5.65	38.95	7.07	63.45	32.000	12.694	1.72	11.87	2.72	24.41
14.000	5.554	4.85	33.42	6.54	58.65	33.000	13.091	1.66	11.43	2.63	23.62
15.000	5.950	4.26	29.37	6.07	54.51	34.000	13.488	1.59	10.99	2.55	22.89
16.000	6.347	3.82	26.31	5.67	50.91	35.000	13.884	1.53	10.55	2.47	22.19
17.000	6.744	3.47	23.96	5.32	47.74	36.000	14.281	1.47	10.12	2.40	21.56
18.000	7.141	3.20	22.10	5.01	44.93	37.000	14.678	1.40	9.69	2.33	20.92
19.000	7.537	2.99	20.60	4.73	42.42	38.000	15.075	1.34	9.26	2.27	20.34
20.000	7.934	2.81	19.36	4.48	40.18	39.000	15.471	1.28	8.84	2.20	19.79
21.000	8.331	18.33	4.25	38.15	40.000	15.868	1.22	8.42	2.15	19.26	

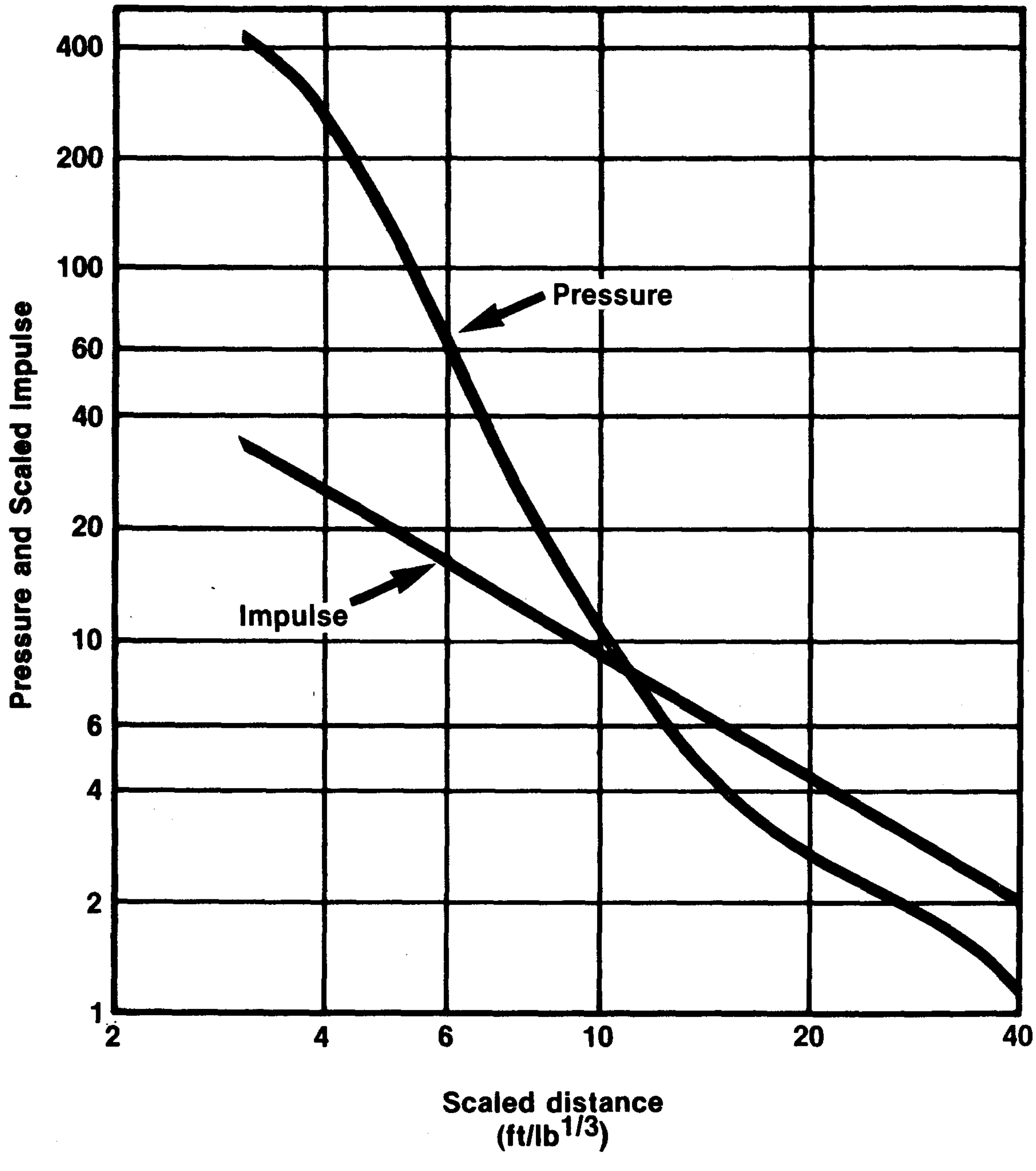


Figure 80. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for PBXW-109 (Precoat) for 45.36 kg Simulated Nutsche Container.

Table 33. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse values for PBXW-109 (Precoat), 90.72 kg

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse psi · ms / $lb^{1/3}$	Scaled Impulse kPa · ms / $kg^{1/3}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse psi · ms / $lb^{1/3}$	Scaled Impulse kPa · ms / $kg^{1/3}$
3.000	1.190	404.58	2789.57	29.24	262.36	22.000	8.727	3.02	20.80	3.44	30.89
4.000	1.587	235.08	1620.88	21.47	192.64	23.000	9.124	2.91	20.07	3.28	29.45
5.000	1.983	112.92	778.58	16.89	151.60	24.000	9.521	2.81	19.38	3.13	28.13
6.000	2.380	57.42	395.89	13.89	124.64	25.000	9.917	2.72	18.72	3.00	26.93
7.000	2.777	32.45	233.75	11.77	105.63	26.000	10.314	2.62	18.07	2.88	25.81
8.000	3.174	20.34	140.28	10.20	91.52	27.000	10.711	2.53	17.42	2.76	24.79
9.000	3.570	13.95	96.17	8.99	80.65	28.000	11.108	2.43	16.77	2.66	23.84
10.000	3.967	10.29	70.96	8.03	72.02	29.000	11.504	2.34	16.10	2.56	22.96
11.000	4.364	8.06	55.57	7.24	65.01	30.000	11.901	2.24	15.43	2.47	22.14
12.000	4.760	6.62	45.63	6.60	59.21	31.000	12.298	2.14	14.74	2.38	21.37
13.000	5.157	5.65	38.92	6.06	54.34	32.000	12.694	2.04	14.05	2.30	20.66
14.000	5.554	4.96	34.22	5.59	50.18	33.000	13.091	1.94	13.35	2.23	19.98
15.000	5.950	4.47	30.81	5.19	46.60	34.000	13.488	1.83	12.64	2.16	19.35
16.000	6.347	4.10	28.26	4.84	43.48	35.000	13.884	1.73	11.93	2.09	18.76
17.000	6.744	3.82	26.31	4.54	40.74	36.000	14.281	1.63	11.22	2.03	18.20
18.000	7.141	3.59	24.77	4.27	38.31	37.000	14.678	1.53	10.52	1.97	17.67
19.000	7.537	3.41	23.52	4.03	36.15	38.000	15.075	1.43	9.83	1.91	17.18
20.000	7.934	3.26	22.48	3.81	34.22	39.000	15.471	1.33	9.16	1.86	16.70
21.000	8.331	3.13	21.59	3.62	32.47	40.000	15.868	1.23	8.50	1.81	16.25

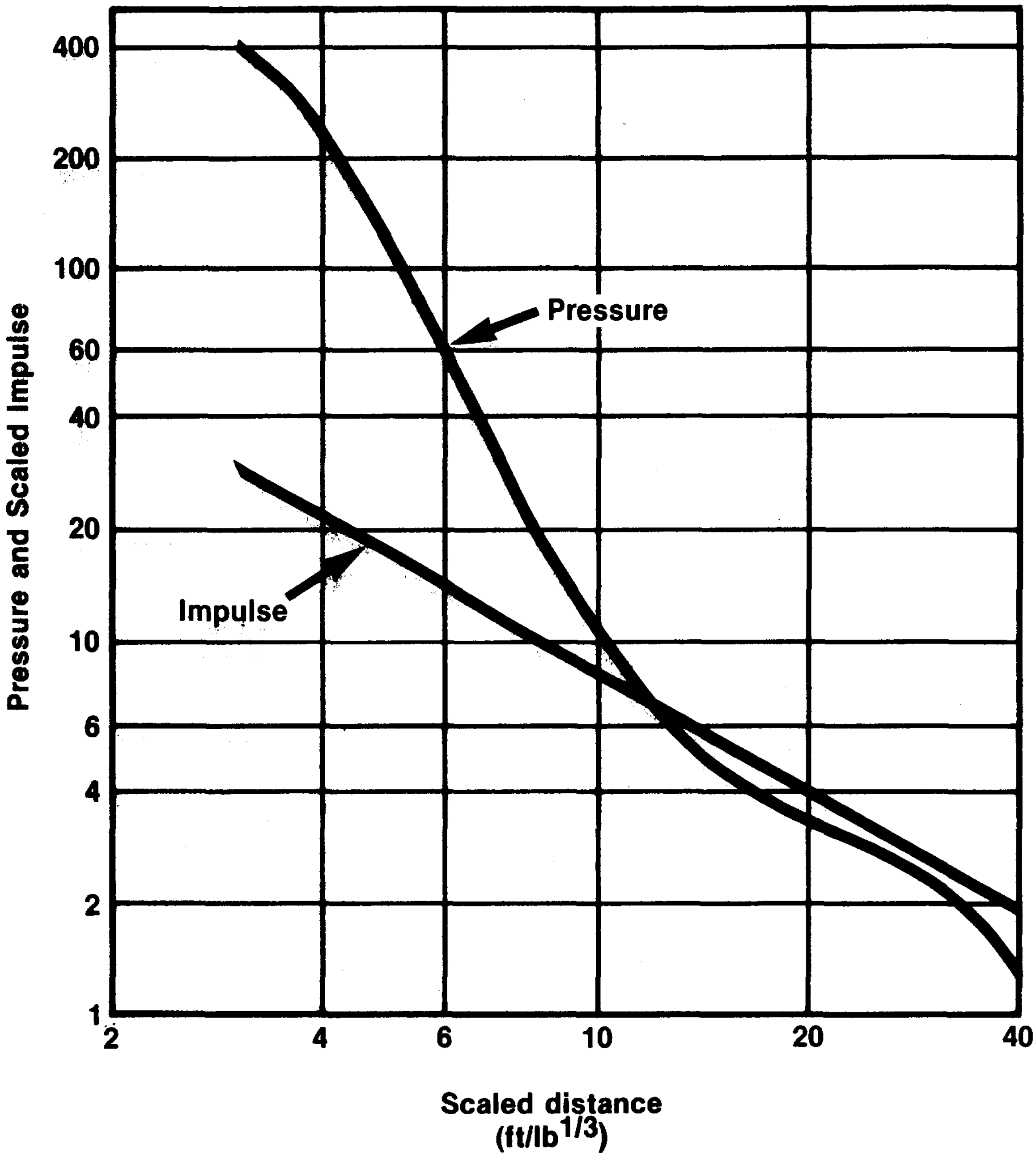


Figure 81. **Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for PBXW-109 (Precoat) for 90.72 kg Orthorhombic Shipping Container.**

OBJECTIVE

The objectives of these studies were to determine the maximum blast pressure and impulse from the detonation of bulk RDX high explosives and in a slurry, in various in-plant and shipping configurations. The measured pressure and impulse were compared with known characteristics of hemispherical TNT data to derive the TNT equivalency.

MATERIAL

The test material was RDX high explosive received wet with isopropyl alcohol in standard shipping containers with a dry weight of 72.6 kg (160 lb). The slurry mixture consisted of RDX in a solution of 60% acetic acid, 32% water and 2% nitric acid. The mixture was encased in plastic containers.

TEST SETUP

Airblast output was evaluated for weights and configurations of RDX representing bulk RDX in scaled-nutches, slurry containers, and a simulated drum. Physical characteristics of the test items are as follows:

(1) Cylindrical fiberboard shipping containers with charge weights of 22.7 and 45.4 kg (50 and 100 lb) with a dimensional scaling factor of 0.63.

(2) Plywood orthorhombic nutsche container filled with charge weights of 27.2 and 54.4 kg (60 and 120 lb). The dimensional scaling factors were 0.37 and 0.46, respectively.

(3) Two sizes of plastic cylinders were used containing 0.95 and 1.68 kg (2.1 and 3.7 lb), respectively.

Each test charge was initiated with a J2 engineers' special blasting cap and a conical-shaped Compositon C4 booster charge. The test charges were placed on mild steel witness plates at ground zero.

INSTRUMENTATION

The instrumentation for the 22.7, 27.2 45.4, and 54.4 kg (50, 60, 100, and 120 lb) tests used 12 piezoelectric side-on pressure transducers were mounted flush to the ground surface in a 90-degree array. Scaled distances ranging from 1.19 to 15.87 $m/kg^{1/3}$ (3.0 to 40.0 $ft/lb^{1/3}$) were held constant throughout the experiments.

Instrumentation used for the slurry tests were different. Piezoresistive pressure transducers manufactured by Tyco Instrument Division of Bytrex Inc. were used. Gages designed to measure peak pressure of 103, 172, 689, 1379, 3447, and 6894 kPa (15, 25, 100, 200, 500, and 1,000 psi) were placed along the gage line in accordance with the predicted pressure values at the gage location. Scaled distances of 0.62, 1.24, 2.98, 4.96, 9.91, and 15.51 $m/kg^{1/3}$ (1.57, 3.13, 6.26, 12.50, 24.99, and 30.09 $ft/lb^{1/3}$) were used in these experiments.

A nominal 20-kHz recording system was used. This system consisted of Endevco models 4401 and 4470 signal conditioners, Dana models 3850V2 and 4472-6 amplifiers and a Sangamo Saber 4 tape recorder operating at 60 ips. The pressure-time data was digitized at 160 samples/ms (6.25 μs/data point).

RESULTS

The results of the slurry tests are given in Table 34 and Figure 82. The results of the orthorhombic configuration tests are given in Table 35 and Figure 83. The combined results of the cylindrical tests are given in Table 36 and Figure 84.

DISCUSSION

Peak pressure for the combined results of the RDX slurry tests were greater than expected at all scaled distances between 1.19 and 7.14 $m/kg^{1/3}$ (3.0 and 18.0 $ft/lb^{1/3}$) and less than expected at scaled distances greater than 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$). Peak pressure values were 1028, 582, 322, 118, 30, and 6.2 kPa (148.8, 84.4, 46.7, 17.1, 4.4, and 0.9 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 1.2, 1.3, 1.4, 1.7, 1.5, and 0.5 times equal amounts of TNT at the same scaled distances, respectively. TNT equivalency values varied as a function of the scaled distance. Scaled positive impulse values followed the same general trend as the pressure values. The scaled positive impulse values were greater than expected at all scaled distances equal to or less than 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$) and less than expected at a scaled distance of 15.87 $m/kg^{1/3}$ (40.0 $ft/lb^{1/3}$). The scaled positive impulse values were 229, 191, 149, 94, 45, and 17.1 kPa-ms/$kg^{1/3}$ (25.5, 21.3, 16.6, 10.4, 5.0, and 1.9 psi-ms/$lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 1.7, 1.8, 1.7, 1.6, 1.3, and 0.97 times equal amounts of TNT at the same scaled distances, respectively.

The combined results of the orthorhombic configuration tests were greater than expected at all scaled distances of the experiment. The pressure values were 3126, 1615, 619, 115, 26, and 11.7 kPa (453.3, 234.2, 89.8, 16.7, 3.7, and 1.7 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 5.3, 5.3, 3.4, 1.7, 1.2, 1.2, and 2.5 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were greater than expected at scaled distances equal to or less than 2.14 $m/kg^{1/3}$ and 7.14 $m/kg^{1/3}$ (5.4 and 18.0 $ft/lb^{1/3}$) and less than expected at scaled distances of 3.57 and 15.87 $m/kg^{1/3}$ (9.0 and 40.0 $ft/lb^{1/3}$). The scaled positive impulse values were 226, 198, 162, 101, 39, and 8.1 kPa-ms/$kg^{1/3}$ (25.2, 22.1, 18.1, 11.2, 4.3, and 0.96 psi-ms/$lb^{1/3}$ at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 1.2, 2.4, 2.3, 0.9, 1,2, and 0.3 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the combined values of the cylindrical tests were greater than expected at all scaled distances of the experiment. The pressure values were 2220, 1308, 545, 117, 31, and 11 kPa (332, 189.7, 79.1, 17, 4.5, and 1.6 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 3.5, 3.9, 2.3, 1.7, 1.6, and 2.0 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were greater than expected at scaled distances equal to or less than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$) and less than expected at all scaled distances equal to or greater than 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$). The scaled positive impulse values were 199, 162, 125, 77, 34, and 10.8 $kPa\text{-}ms/kg^{1/3}$ (22.2, 18, 14, 8.6, 3.8, and 1.2 $psi\text{-}ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 1.3, 1.5, 1.1, 1.3, 0.9, and 0.5 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) The RDX slurry results varied as a function of the scaled distances.

(2) The measure pressure and impulse values for the slurry mixture are indicative of geometric and containment effects rather than differences in charge composition.

(3) RDX, when detonated, can generate pressure and positive impulse values which are greater than those produced by equal amounts of TNT at the same scaled distances.

(4) The blast output from RDX is dependent upon the configuration from which it detonates.

(5) To within experimental limits, blast pressure and impulse scale as a cube-root functrion of the charge weight.

Table 34. Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse Values for RDX Slurry in Cylindrical Configuration.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	148.76	1025.70	26.53	238.12	22.000	8.727	2.94	20.25	3.97	35.64
4.000	1.587	84.40	581.94	21.31	191.23	23.000	9.124	2.69	18.55	3.77	33.81
5.000	1.983	54.38	374.92	17.75	159.27	24.000	9.521	2.47	17.06	3.58	32.14
6.000	2.380	39.97	261.78	15.16	136.03	25.000	9.917	2.28	15.74	3.41	30.60
7.000	2.777	28.02	193.22	13.19	118.36	26.000	10.314	2.11	14.57	3.25	29.19
8.000	3.174	21.54	148.52	11.64	104.47	27.000	10.711	1.96	13.53	3.11	27.87
9.000	3.570	17.08	117.76	10.39	93.26	28.000	11.108	1.83	12.59	2.97	26.66
10.000	3.967	13.88	95.69	9.37	84.04	29.000	11.504	1.70	11.75	2.84	25.53
11.000	4.364	11.50	79.31	8.51	76.33	30.000	11.901	1.59	10.99	2.73	24.47
12.000	4.760	9.69	66.82	7.78	69.78	31.000	12.298	1.49	10.31	2.62	23.49
13.000	5.157	8.28	57.07	7.15	64.15	32.000	12.694	1.40	9.68	2.52	22.57
14.000	5.554	7.15	49.32	6.61	59.28	33.000	13.091	1.32	9.11	2.42	21.71
15.000	5.950	6.24	43.05	6.13	55.01	34.000	13.488	1.25	8.59	2.33	20.90
16.000	6.347	5.50	37.91	5.71	51.25	35.000	13.884	1.18	8.12	2.24	20.14
17.000	6.744	4.88	33.64	5.34	47.91	36.000	14.281	1.11	7.68	2.16	19.43
18.000	7.141	4.36	30.06	5.01	44.92	37.000	14.678	1.06	7.27	2.09	18.75
19.000	7.537	3.92	27.03	4.71	42.24	38.000	15.075	1.00	6.90	2.02	18.12
20.000	7.934	3.54	24.43	4.44	39.82	29.000	15.471	0.95	6.56	1.95	17.51
21.000	8.331	3.22	22.19	4.19	37.63	40.000	15.868	0.90	6.24	1.89	16.94

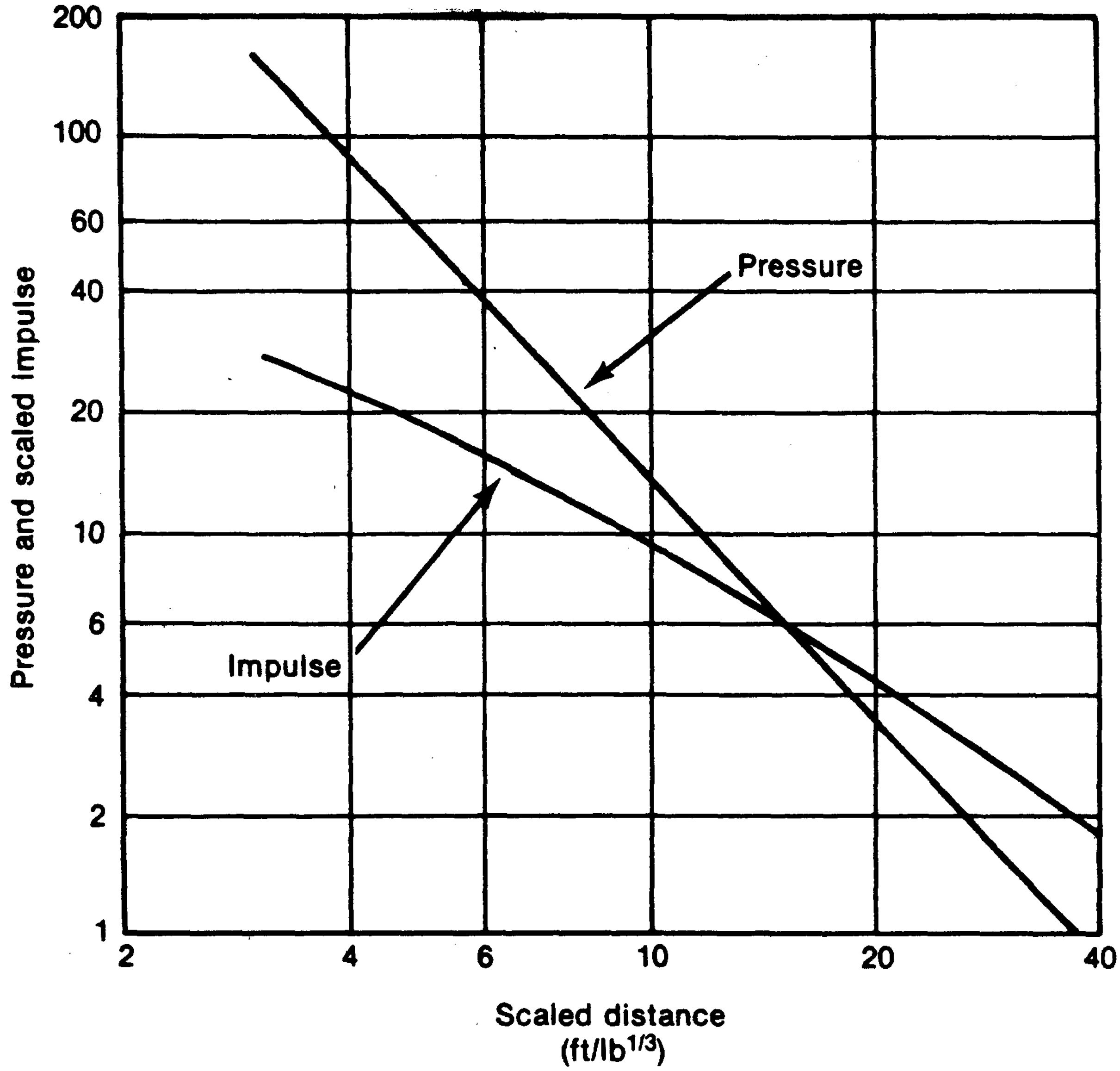


Figure 82. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for RDX Slurry in a Cylindrical Configuration.

Table 35. Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse Values for RDX 98/2 in Orthorhombic Containers, L/D = 0.6:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	453.26	3125.20	25.22	226.33	22.000	8.727	2.94	20.31	3.09	27.75
4.000	1.587	234.15	1614.49	22.12	198.51	23.000	9.124	2.82	19.45	2.86	25.66
5.000	1.983	116.38	802.44	19.20	172.29	24.000	9.521	2.71	18.71	2.65	23.77
6.000	2.380	62.69	432.24	16.66	149.53	25.000	9.917	2.62	18.06	2.46	22.06
7.000	2.777	37.17	256.29	14.52	130.27	26.000	10.314	2.54	17.49	2.29	20.51
8.000	3.174	24.05	165.80	12.71	114.05	27.000	10.711	2.46	16.96	2.13	19.11
9.000	3.570	16.74	115.44	11.19	100.38	28.000	11.108	2.39	16.48	1.99	17.82
10.000	3.967	12.39	85.40	9.90	88.81	29.000	11.504	2.33	16.04	1.86	16.66
11.000	4.366	9.63	66.40	8.80	78.97	30.000	11.901	2.27	15.62	1.74	15.59
12.000	4.760	7.80	53.76	7.86	70.55	31.000	12.298	2.21	15.22	1.63	14.61
13.000	5.157	6.53	45.00	7.05	63.30	32.000	12.694	2.15	14.84	1.53	13.71
14.000	5.554	5.62	38.72	6.35	57.02	33.000	13.091	2.10	14.47	1.44	12.88
15.000	5.950	4.94	34.07	5.75	51.56	34.000	13.488	2.05	14.11	1.35	12.12
16.000	6.347	4.43	30.54	5.21	46.79	35.000	13.884	1.99	13.76	1.27	11.41
17.000	6.744	4.03	27.81	4.75	42.59	36.000	14.281	1.94	13.41	1.20	10.76
18.000	7.141	3.72	25.65	4.33	38.89	37.000	14.678	1.89	13.06	1.13	10.16
19.000	7.537	3.47	23.91	3.97	35.61	38.000	15.075	1.84	12.72	1.07	9.60
20.000	7.934	3.26	22.48	3.64	32.69	39.000	15.471	1.79	12.37	1.01	9.08
21.000	8.331	3.09	21.30	3.35	30.09	40.000	15.868	1.74	12.03	0.96	8.59

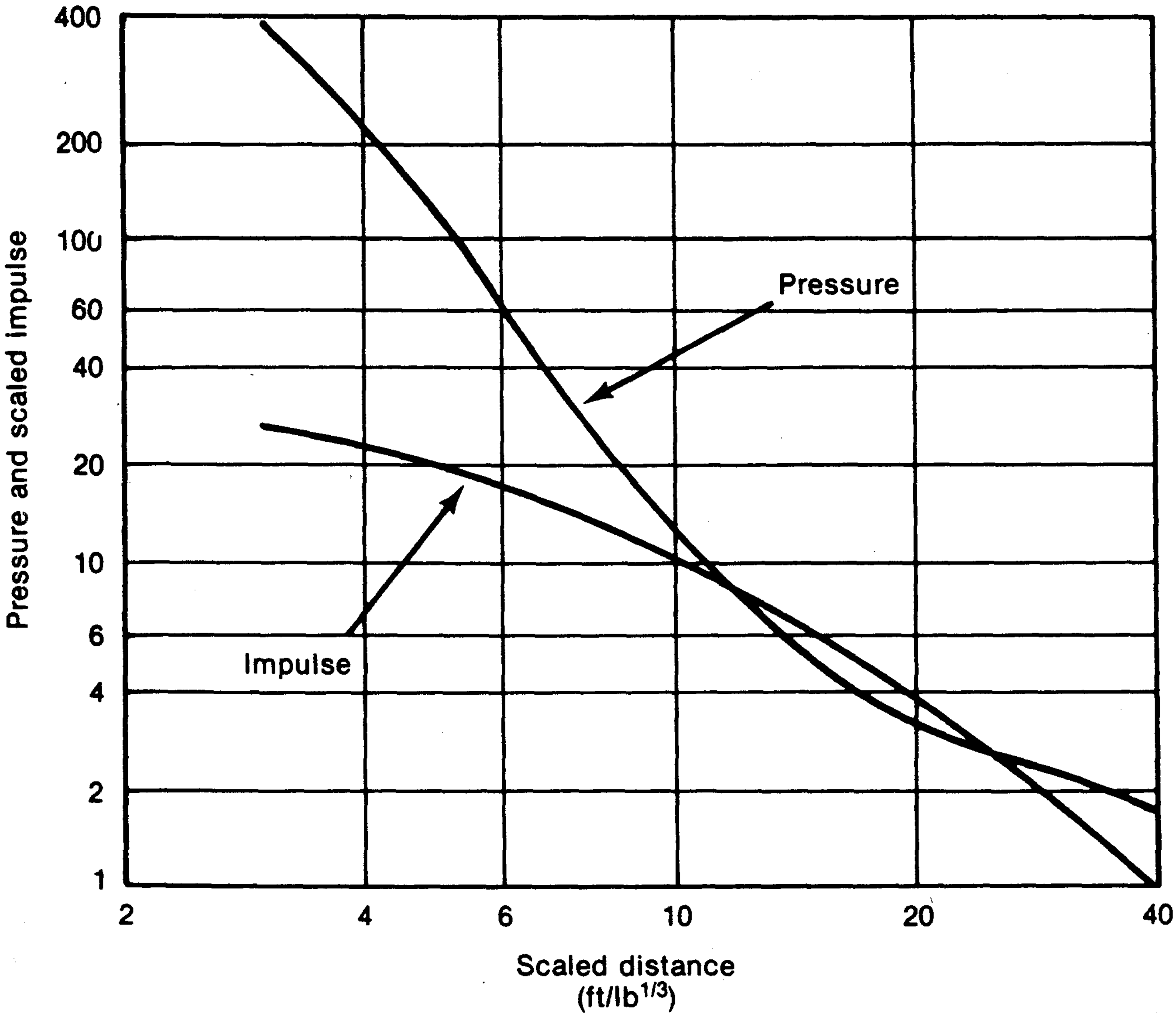


Figure 83. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for RDX in Orthorhombic Containers, L/D = 0.6:1.

Table 36. Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse Values for RDX 98/2 in Cylindrical Configuration, L/D = 1:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	332.01	2289.23	22.22	199.40	22.000	8.727	3.61	24.90	2.93	26.31
4.000	1.587	189.73	1308.17	18.03	161.77	23.000	9.124	3.45	23.79	2.76	24.76
5.000	1.983	100.41	692.30	15.03	134.91	24.000	9.521	3.30	22.78	2.60	23.35
6.000	2.380	56.80	391.66	12.80	114.85	25.000	9.917	3.17	21.84	2.46	22.06
7.000	2.777	35.14	242.32	11.07	99.36	26.000	10.314	3.04	20.97	2.33	20.88
8.000	3.174	23.62	162.87	9.70	87.08	27.000	10.711	2.92	20.13	2.21	19.79
9.000	3.570	17.03	117.42	8.59	77.12	28.000	11.108	2.80	19.33	2.09	18.79
10.000	3.967	13.00	89.66	7.68	68.90	29.000	11.504	2.69	18.56	1.99	17.86
11.000	4.364	10.40	71.71	6.91	62.02	30.000	11.901	2.58	17.81	1.89	17.00
12.000	4.760	8.64	59.56	6.26	56.19	31.000	12.298	2.48	17.08	1.81	16.20
13.000	5.157	7.39	50.98	5.71	51.20	32.000	12.694	2.37	16.36	1.72	15.46
14.000	5.554	6.49	44.71	5.22	46.88	33.000	13.091	2.27	15.66	1.65	14.72
15.000	5.950	5.80	40.00	4.80	43.12	34.000	13.488	2.17	14.96	1.57	14.12
16.000	6.347	5.27	36.36	4.44	39.81	35.000	13.884	2.07	14.28	1.51	13.52
17.000	6.744	4.85	33.47	4.11	36.89	36.000	14.281	1.97	13.61	1.44	12.95
18.000	7.141	4.52	31.13	3.82	34.29	37.000	14.678	1.88	12.95	1.38	12.42
19.000	7.537	4.23	29.19	3.56	31.97	38.000	15.075	1.78	12.30	1.33	11.93
20.000	7.934	4.00	27.56	3.33	29.89	39.000	15.471	1.69	11.67	1.28	11.46
21.000	8.331	3.79	26.14	3.12	28.01	40.000	15.868	1.60	11.05	1.23	11.01

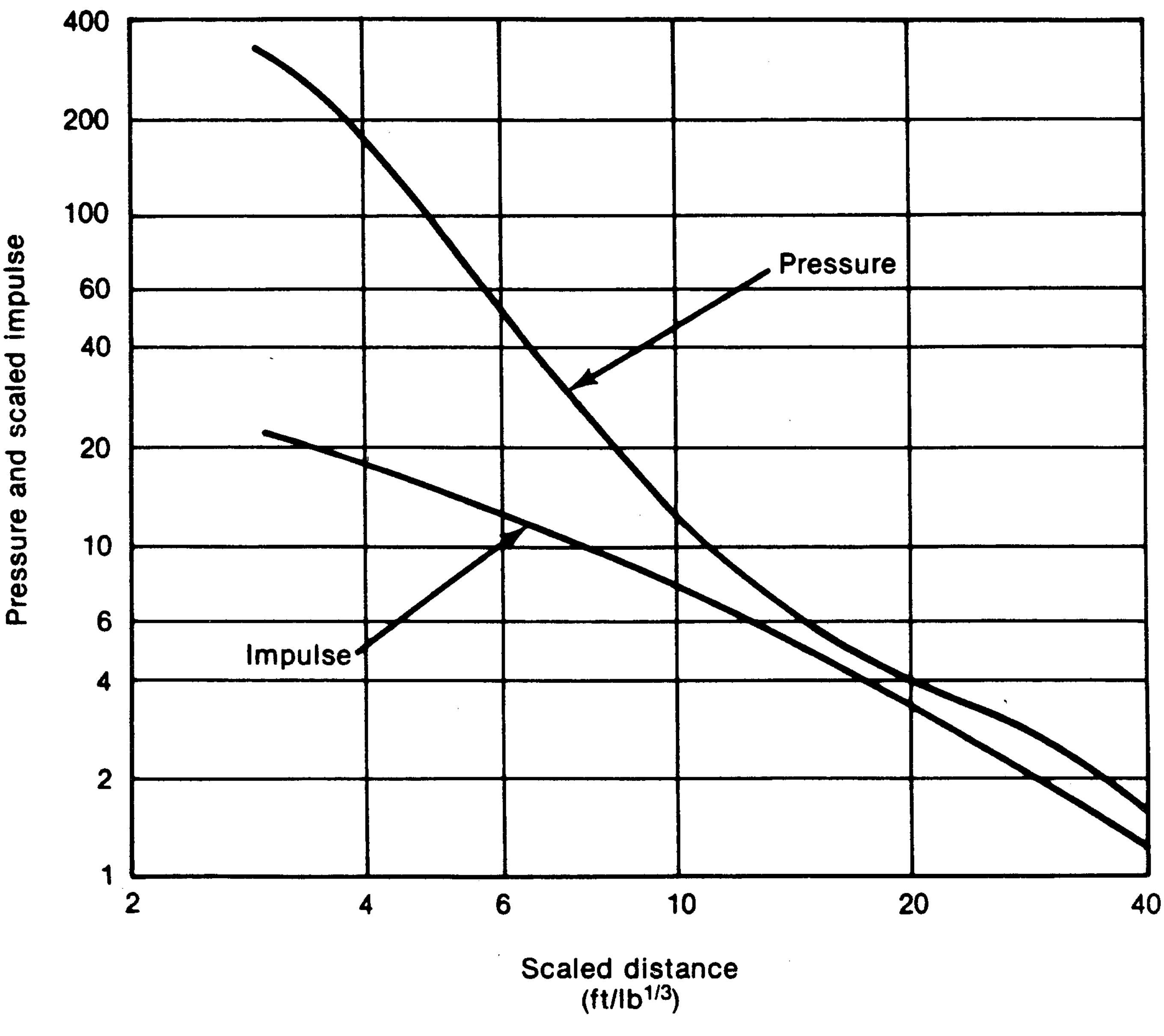


Figure 84. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for RDX in Cylindrical Configuration, L/D = 1:1.

OBJECTIVE

The objective of this study was to perform standard hemispherical TNT equivalency tests using cast hemispherical TNT as calibration tests and to determine the maximum output from the detonation of flaked TNT in in-plant configurations.

MATERIALS

The cast hemisphere charges had a L/D ratio of 1:1 and ranged from 8.16 to 9.53 kg (18 to 21 lb) in weight. Each charge was x-rayed for voids and cracks. The flaked TNT was received in bulk form in 24.9 kg (55 lb) net weight in telescoping fiberboard boxes.

TEST SETUP

Airblast output was evaluated for weights and configurations of hemispherical and bulk flaked TNT. Physical characteristics are as folows:

(1) Cast hemispheres with a 1:1 L/D ratio.

(2) Cylindrical containers filled with charge weights of 27.2, 45.4, and 68.0 kg (60, 100 and 150 lb with scaling factors of 0.73, 0.87, and 1.0, respectively. The cylindrical containers were constructed from fiberboard.

(3) Orthorhombic fiberboard containers filled with charge weights of 27.2, 45.4, and 68.0 kg (60, 100 and 150 lb) with scaling factors of 0.73, 0.87, and 1.0, respectively.

(4) Truncated prisms constructed from plywood representing in-plant hoppers were filled with 45.4, 68.0, and 90.7 kg (100, 150 and 200 lbs). The dimensional scaling factors were 0.73, 0.84, and 0.92, respectively.

A conical-shaped booster charge with a L/D ratio of 1:2 was centered atop the test charges and initiated by a J2 engineers' special blasting cap. All test charges were placed on a mild steel witness plate at ground zero.

INSTURMENTATION

Twelve piezoelectric pressure transducers mounted flush to the ground surface in a 90-degree array. Scaled distances ranging from 1.19 to 15.87 m/kg$^{1/3}$ (3.0 to 40.0 ft/lb$^{1/3}$) were held constant throughout the experiments.

RESULTS

Results of the cast hemispherical tests are given in Table 37 and Figure 85. The values shown are one standard deviation of the mean. Results of the cylindrical flake TNT are given in Table 38 and Figure 86. The combined results of the orthorhombic flaked TNT tests are given in Table 39 and Figure 87. The combined values of the truncated prism (hopper tests) are given in Table 40 and Figure 88. All data for the flake TNT tests are within one standard deviation of the mean.

DISCUSSION

Peak pressure values for the cast hemispherical TNT with a L/D ratio of 1:1 were greater than expected at all scaled distances equal to or less than 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$) and less than expected at a scaled distance of 15.87 $m/kg^{1/3}$ (40.0 $ft/lb^{1/3}$). The pressure values were 1038, 596, 334, 128, 33, and 7.1 kPa (150.6, 86.5, 48.5, 18.2, 4.8, and 1.03 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values when compared to the standard reference curve(1) equate to 1.1, 1.3, 1.6, 1.5, 1.6, and 0.7 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were less than expected at scaled distances equal to or less than 1.59 $m/kg^{1/3}$ (4.0 $ft/lb^{1/3}$) and greater than expected at scaled distances of 2.14, 3.57, and 7.14 $m/kg^{1/3}$ (5.4, 9.0, and 18.0 $ft/lb^{1/3}$) and less than expected at a scaled distance of 15.87 $m/kg^{1/3}$ (40.0 $ft/lb^{1/3}$). The scaled positive impulse values were 148, 131, 110, 78, 43, and 16.8 kPa-ms/$kg^{1/3}$ (16.6, 14.6, 12.3, 8.7, 4.7, and 1.87 psi-ms/$lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These values when compared to the standard reference curve(1) equate to 0.9, 0.9, 1.1, 1.2, 1.3, and 0.9 times equal amounts of TNT at the same scaled distances respectively.

The higher pressure values were attributed to the state-of-the-art instrumentation systems whereby the resolution and frequency response of the currrent instrumentation system is 500 kHz versus the 20 kHz systems used to develop the standard reference curve(1). McKown and Wilcox(19) have shown that there is a measurable difference in peak pressure values predicated upon the frequency response of the system. This phenomena has also been confirmed by the author while conducting other studies.

The combined peak pressure values for the flaked TNT in cylindrical containers were greater than expected at all scaled distances of the experiment. The high values are due in part to the geometry and the L/D ratio of being 1.8:1. The pressure values were 2675, 1112, 453, 114, 34, and 9.5 kPa (338, 161.3, 65.7, 16.2, 4.9, and 1.38 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These values when compared to the standard reference curve(1) equate to 3.6, 3.1, 2.3, 1.6, 1.8, and 1.4 times equal amounts of hemispherical TNT at the same scaled distances, respectively. Scaled positive impulse values were greater than expected at scaled distances equal to or less than 2.14 $m/kg^{1/3}$ (5.4 $ft/lb^{1/3}$) and less than expected at scaled distances equal to or greater than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$). The combined scaled positive impulse for flaked TNT in cylindrical configuration with a L/D ratio of 1.8:1 were 314, 208, 123, 57, 36, and 16.1 kPa-ms/kg$^{1/3}$ (34.96, 23.2, 13.7, 6.4, 4.01 and 1.79 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These values when compared to the standard reference curve(1) were 2.7, 2.0, 1.3, 0.7, 0.95, and 0.9 times equal amounts of hemispherical TNT at the same scaled distances, respectively.

The combined pressure values for the orhtorhombic configuration with a L/D ratio of 0.84:1 were greater than expected at scaled distances equal to or less than 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$) and less than expected at a scaled distance of 15.87 m/kg$^{/3}$ (40.0 ft/lb^1/3). The pressure values were 2859, 1467, 540, 99, 24, and 6.7 kPa (414.6, 212.7, 78.3, 14.3, 3.5, and 0.97 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These values when compared to the standard reference curve(1) equate to 4.7, 4.5, 2.9, 1.3, 1.0, and 0.9 times equal amounts of hemispherical TNT with a L/D ratio of 1:1 at the same scaled distances, respectively. The combined scaled positive impulse values were greater than expected at scaled distances equal to or less than 2.14 m/kg$^{\hat{}1/3}$ (5.4 ft/lb$^{1/3}$) less than expected at scaled distances of 3.57 and 7.14 m/kg$^{1/3}$ (9.0 and 18.0 ft/lb$^{1/3}$) and equal to the expected value at a scaled distance of 15.87 m/kg$^{1/3}$ (40.0 ft/lb$^{1/3}$). The scaled positive impulse values were 314, 304, 160, 48, 34, and 17.1 kPa-ms/kg$^{1/3}$ (35, 33.9, 17.8, 5.3, 3.8, and 1.9 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values when compared to the standard TNT reference curve(1) equate to 2.7, 3.8, 2.0, 0.6, 0.9, and 1.0 times equal amounts of hemispherical TNT at the same scaled distances, respectively.

Combined pressure values for the truncated prism (hopper) configuration were greater than expected at all scaled distances equal to or less than 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$) and less than expected at a scaled distance of 15.87 m/kg$^{1/3}$ (40.0 ft/lb$^{1/3}$). The pressure values were 2788, 1582, 631, 119, 26, and 7.2 kPa (404.3, 229.4, 91.5, 17.3, 3.7, and 1.04 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values when compared to the standard reference curve(1) equate to 4.6, 5.0, 3.6, 1.7, 1.2, and 0.7 times equal amounts of hemispherical TNT at the same scaled distances, respectively. The scaled positive impulse values for the truncated prism were greater than expected at scaled distances equal to or less than 2.14 m/kg$^{1/3}$ (5.4 ft/lb$^{1/3}$) equal to or less than expected at scaled distances equal to or greater than 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$). The scaled positive impulse values for the truncated prisim were 335, 321, 179, 59, 37, and 15.97 kPa-ms/kg$^{1/3}$ (37.3, 35.82, 19.97, 6.48, 4.12, and 1.78 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0 and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values when compared to the standard TNT reference curve(1) equate to 3.0, 4.2, 2.4, 0.8, 1.0, and 0.9 times equal amounts of TNT at the same scaled distances, respectively.

The large differences in the equivalency for the flake TNT tests in the cylindrical, orthorhombic, and truncated prism configurations are due primarily to the geometry of the tests. The L/D ratios and the various geometries have a significant effect on the test results. There are some additional contributions due to the type of instrumentation used and the frequency response of the instrumentation. However, the differences noted at the various scaled distances are attributed to the geometry. The pressure values at the close-in scaled distances for the truncated prism and the cylindrical configurations indicate this difference. The same general trends are also noted in the differences at the far-field scaled distances.

CONCLUSIONS

(1) Peak pressure values for cast hemispherical TNT were greater than the expected values of the standard reference curves at scaled distances equal to or less than 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$) and less than expected at a scaled distance of 15.87 $m/kg^{1/3}$ (40.0 $ft/lb^{1/3}$).

(2) The differences in pressure were attributed to the difference in the state-of-the-art instrumentation used in the measurements.

(3) The blast output from bulk flake TNT is dependent upon the configuration from which it is detonated.

(4) To within experimental limits, blast pressure and impulse scale as a cube root function of the charge weight.

Table 37. Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for Cast Hemispherical TNT, L/D = 1:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	140.43	968.24	17.39	156.07	22.000	8.727	3.07	21.16	3.93	35.30
4.000	1.587	90.28	622.51	14.82	132.98	23.000	9.124	2.85	19.62	3.75	33.65
5.000	1.983	58.22	401.43	12.89	115.68	24.000	9.521	2.65	18.25	3.58	32.10
6.000	2.380	39.44	271.92	11.42	102.50	25.000	9.917	2.47	17.02	3.41	30.64
7.000	2.777	28.15	194.12	10.27	92.15	26.000	10.314	2.31	15.90	3.26	29.27
8.000	3.174	21.05	145.14	9.34	83.78	27.000	10.711	2.16	14.89	3.12	27.98
9.000	3.570	16.36	112.80	8.56	76.85	28.000	11.108	2.03	13.97	2.98	26.76
10.000	3.967	13.13	90.52	7.91	70.99	29.000	11.504	1.90	13.12	2.85	25.60
11.000	4.364	10.81	74.56	7.35	65.94	30.000	11.901	1.79	12.34	2.73	24.51
12.000	4.760	9.10	62.77	6.86	61.53	31.000	12.298	1.69	11.62	2.62	23.47
13.000	5.157	7.80	53.80	6.42	57.64	32.000	12.694	1.59	10.95	2.51	22.49
14.000	5.554	6.79	46.80	6.04	54.16	33.000	13.091	1.50	10.33	2.40	21.55
15.000	5.950	5.98	41.23	5.69	51.03	34.000	13.488	1.41	9.75	2.30	20.66
16.000	6.347	5.32	36.70	5.37	48.19	35.000	13.884	1.34	9.21	2.21	19.82
17.000	6.744	4.78	32.96	5.08	45.59	36.000	14.281	1.26	8.70	2.12	19.01
18.000	7.141	4.33	29.83	4.81	43.20	37.000	14.678	1.19	8.23	2.03	18.24
19.000	7.537	3.94	27.17	4.57	41.00	38.000	15.075	1.13	7.78	1.95	17.51
20.000	7.934	3.61	24.89	4.34	38.97	39.000	15.471	1.07	7.44	1.87	16.81
21.000	8.331	3.32	22.90	4.13	37.07	40.000	15.868	1.01	6.96	1.80	16.14

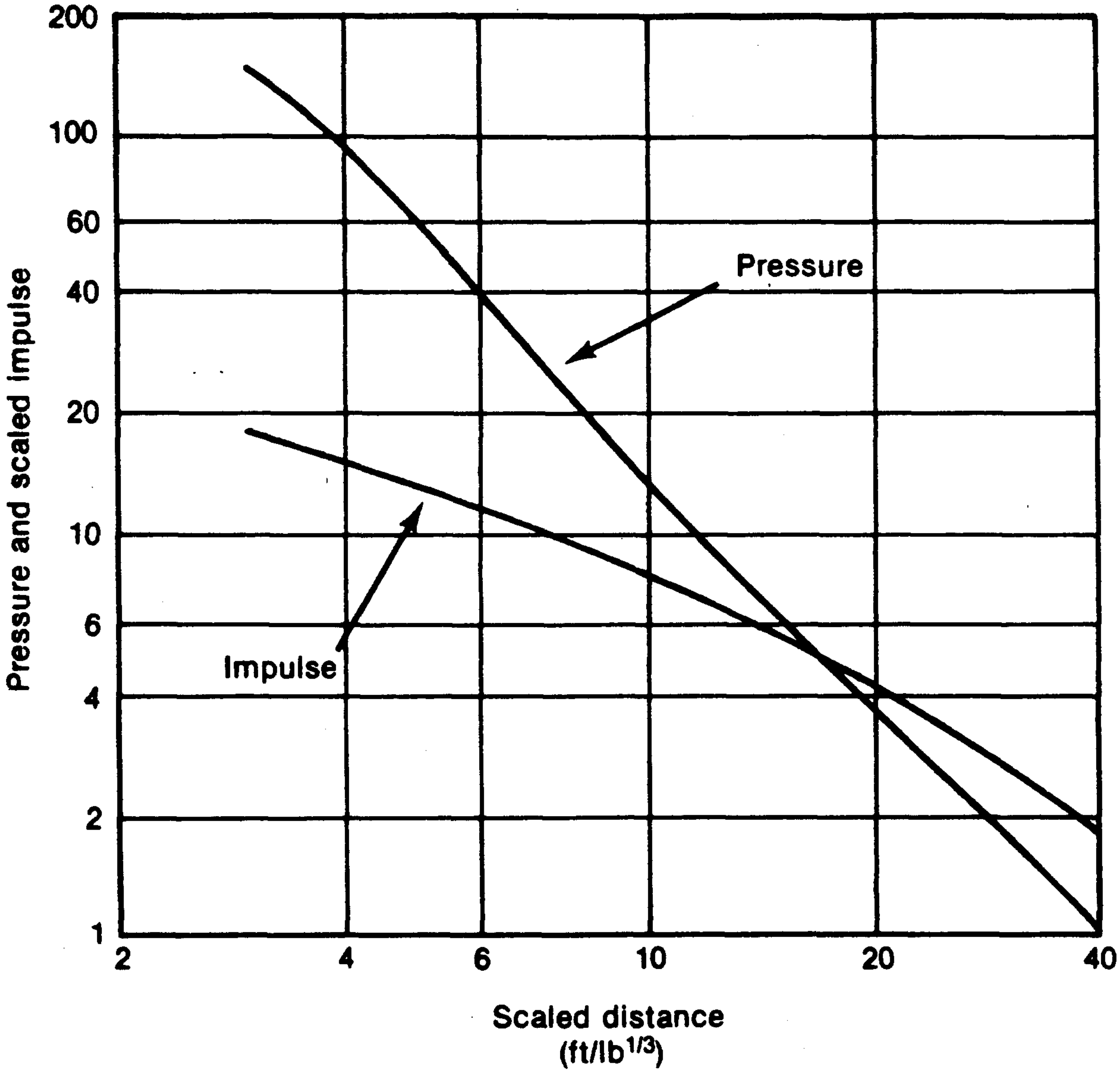


Figure 85. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for Cast Hemispherical TNT, L/D = 1:1.

Table 38. Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse Values for Flake TNT in Cylindrical Configuration, L/D = 1.8:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	338.08	2331.04	34.96	313.70	22.000	8.727	3.81	26.29	3.69	33.16
4.000	1.587	161.29	1112.86	23.22	208.26	23.000	9.124	3.61	24.92	3.61	32.43
5.000	1.983	82.94	571.88	15.73	141.20	24.000	9.521	3.43	23.65	3.53	31.67
6.000	2.380	47.98	330.84	11.47	102.90	25.000	9.917	3.26	22.46	3.44	30.88
7.000	2.777	30.84	212.65	8.96	80.39	26.000	10.314	3.09	21.34	3.35	30.05
8.000	3.174	21.58	148.83	7.41	66.47	27.000	10.711	2.94	20.27	3.25	29.18
9.000	3.570	16.15	111.38	6.40	57.45	28.000	11.108	2.79	19.25	3.15	28.27
10.000	3.967	12.74	87.83	5.72	51.36	29.000	11.504	2.65	18.27	3.04	27.32
11.000	4.364	10.47	72.17	5.25	47.11	30.000	11.901	2.51	17.33	2.94	26.34
12.000	4.760	8.88	61.24	4.91	44.05	31.000	12.298	2.38	16.42	2.82	25.34
13.000	5.157	7.73	53.30	4.66	41.80	32.000	12.694	2.25	15.54	2.71	24.32
14.000	5.554	6.86	47.33	4.47	40.09	33.000	13.091	2.13	14.69	2.59	23.28
15.000	5.950	6.19	42.71	4.32	38.76	34.000	13.488	2.01	13.87	2.48	22.23
16.000	6.347	5.66	39.02	4.20	37.68	35.000	13.884	1.90	13.08	2.36	21.18
17.000	6.744	5.22	36.01	4.10	36.78	36.000	14.281	1.79	12.31	2.24	20.12
18.000	7.141	4.86	33.49	4.01	35.98	37.000	14.678	1.68	11.58	2.13	19.08
19.000	7.537	4.54	31.33	3.93	35.25	38.000	15.075	1.58	10.87	2.01	18.05
20.000	7.934	4.27	29.46	3.85	34.55	39.000	15.471	1.48	10.19	1.90	17.03
21.000	8.331	4.03	27.79	3.77	33.86	40.000	15.868	1.38	9.54	1.79	16.03

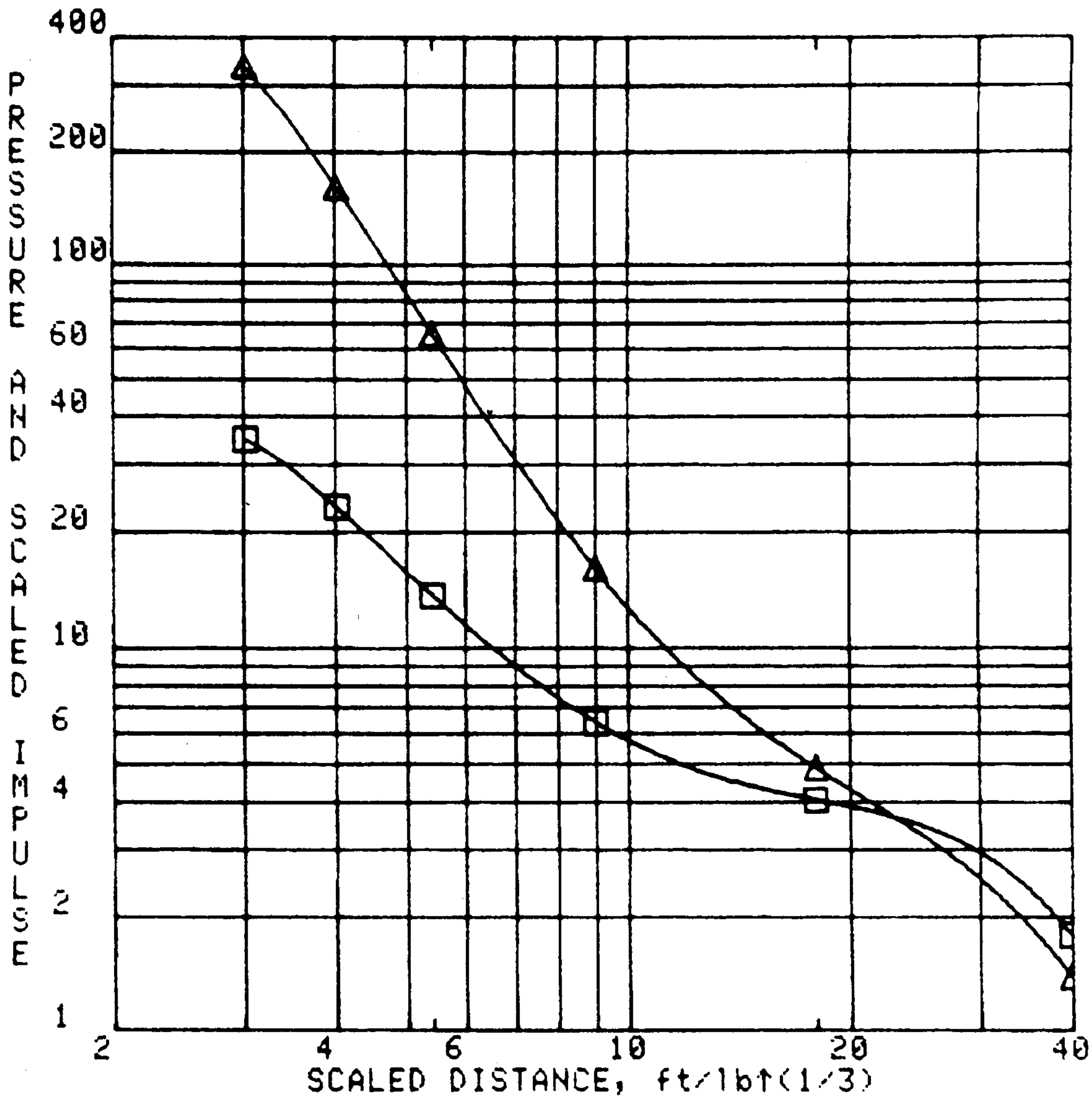


Figure 86. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for Flake TNT in Cylindrical Configurartion, L/D = 1.8:1.

Table 39. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for Flake TNT in Orthorhombic Configuration, L/D = 0.84:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	414.64	2858.97	35.02	314.25	22.000	8.727	2.73	18.85	4.22	37.86
4.000	1.587	212.66	1466.30	33.85	303.75	23.000	9.126	2.60	17.89	4.29	38.46
5.000	1.983	102.48	706.61	21.59	193.75	24.000	9.521	2.47	17.02	4.33	38.86
6.000	2.380	53.93	371.88	13.48	121.00	25.000	9.917	2.35	16.20	4.35	39.02
7.000	2.777	31.61	217.98	9.07	81.40	26.000	10.314	2.24	15.42	4.34	28.93
8.000	3.174	20.42	140.78	6.67	59.84	27.000	10.711	2.13	14.67	4.30	38.57
9.000	3.570	14.29	98.55	5.31	47.66	28.000	11.108	2.02	13.95	4.23	37.94
10.000	3.967	10.68	73.64	4.52	40.55	29.000	11.504	1.92	13.26	4.13	37.04
11.000	4.364	8.61	57.97	4.05	36.37	30.000	11.901	1.82	12.58	4.00	35.90
12.000	4.760	6.90	47.57	3.79	33.98	31.000	12.298	1.73	11.92	3.85	34.52
13.000	5.157	5.85	40.36	3.65	32.74	32.000	12.694	1.63	11.27	3.67	32.95
14.000	5.554	5.10	35.15	3.60	32.28	33.000	13.091	1.54	10.64	3.48	31.21
15.000	5.950	4.54	31.27	3.61	32.35	34.000	13.488	1.45	10.02	3.27	29.33
16.000	6.347	4.10	28.29	3.66	32.80	35.000	13.884	1.37	9.42	3.05	27.36
17.000	6.744	3.76	25.93	3.23	33.50	36.000	14.281	1.28	8.84	2.82	25.36
18.000	7.141	3.48	24.02	3.83	34.36	37.000	14.678	1.20	8.27	2.60	23.29
19.000	7.537	3.25	22.43	3.93	35.29	38.000	15.075	1.12	7.72	2.37	21.25
20.000	7.934	3.06	21.07	4.04	36.23	39.000	15.471	1.04	7.20	2.15	19.25
21.000	8.331	2.89	19.89	4.13	37.10	40.000	15.868	0.97	6.69	1.93	17.32

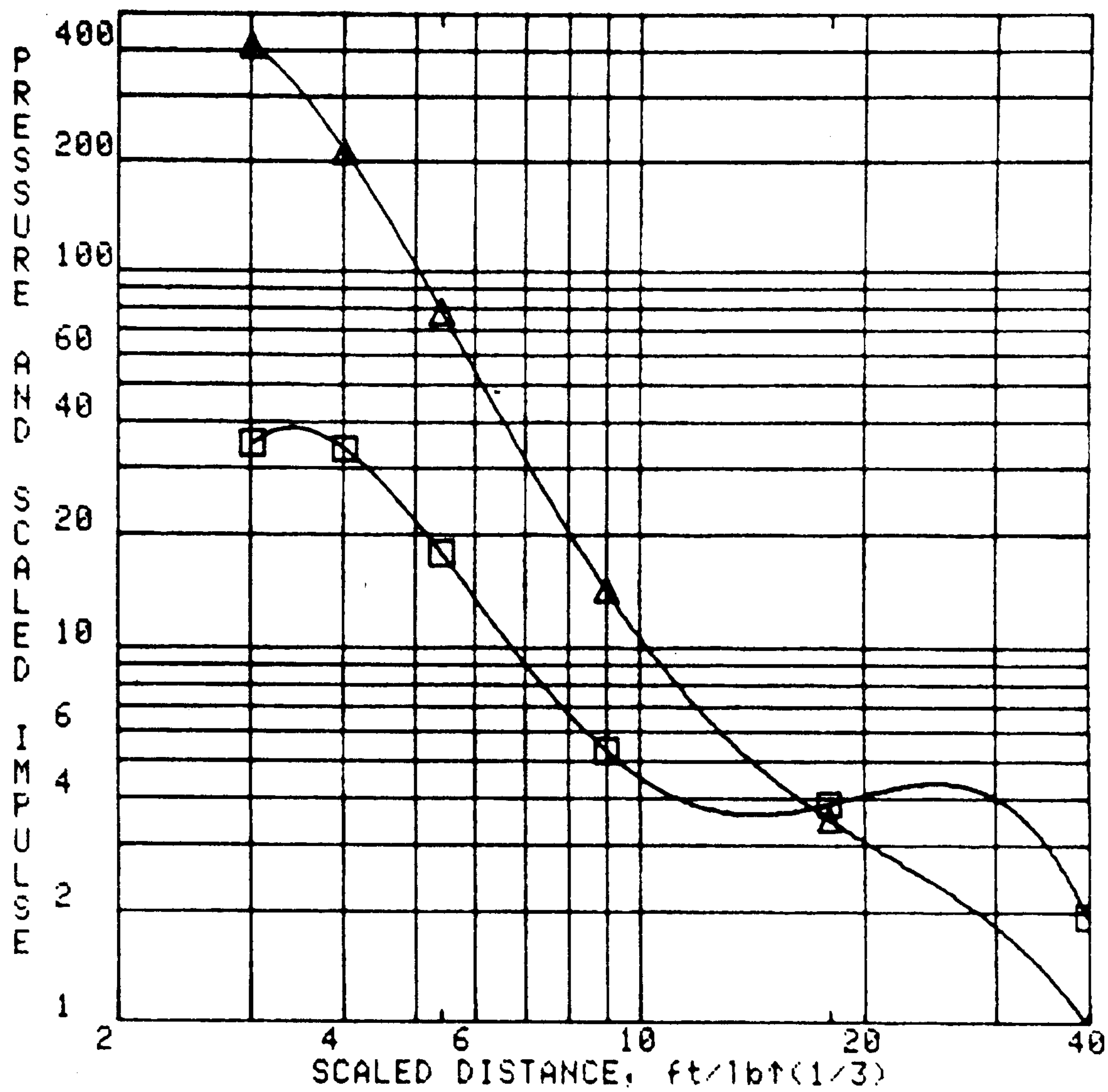


Figure 87. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for Flake TNT in Orthorhombic Configuration, L/D = 0.84:1.

Table 40. Summary of Results for Hemispherical Surface Bursts, Peak Pressure and Scaled Positive Impulse Values for Flake TNT in Truncated Prism (Hopper) Configuration, L/D=2:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	404.31	2787.68	37.30	334.76	22.000	8.727	2.80	19.29	4.23	37.92
4.000	1.587	229.36	1581.47	35.82	321.42	23.000	9.124	2.64	18.19	4.23	37.93
5.000	1.983	117.77	812.04	23.82	213.79	24.000	9.521	2.49	17.19	4.21	37.78
6.000	2.380	64.25	442.99	15.51	139.22	25.000	9.917	2.36	16.28	4.17	37.44
7.000	2.777	38.31	264.14	10.76	96.59	26.000	10.314	2.26	15.44	4.11	36.91
8.000	3.174	26.85	171.37	8.06	72.35	27.000	10.711	2.13	14.66	4.03	36.19
9.000	3.570	17.33	119.51	6.48	58.11	28.000	11.108	2.02	13.93	3.93	35.27
10.000	3.967	12.83	88.48	5.51	49.45	29.000	11.504	1.92	13.23	3.81	34.17
11.000	4.364	9.97	68.78	4.91	44.07	30.000	11.901	1.82	12.57	3.67	32.90
12.000	4.760	8.07	55.62	4.54	40.72	31.000	12.298	1.73	11.93	3.51	31.48
13.000	5.157	6.74	46.45	4.31	38.67	32.000	12.694	1.64	11.32	3.34	29.53
14.000	5.554	5.78	39.82	4.18	37.49	33.000	13.091	1.56	10.73	3.15	28.28
15.000	5.950	5.06	34.87	4.11	36.90	34.000	13.488	1.47	10.17	2.96	26.55
16.000	6.347	4.51	31.07	4.09	36.70	35.000	13.884	1.40	9.62	2.76	24.77
17.000	6.744	4.07	28.07	4.10	36.76	36.000	14.281	1.32	9.09	2.56	22.96
18.000	7.141	3.72	25.65	4.12	36.98	37.000	14.678	1.24	8.58	2.36	21.16
19.000	7.537	3.43	23.66	4.15	37.26	38.000	15.075	1.17	8.08	2.16	19.38
20.000	7.934	3.19	21.98	4.18	37.55	39.000	15.471	1.10	7.61	1.97	17.65
21.000	8.331	2.98	20.55	4.21	37.78	40.000	15.868	1.04	7.15	1.78	15.97

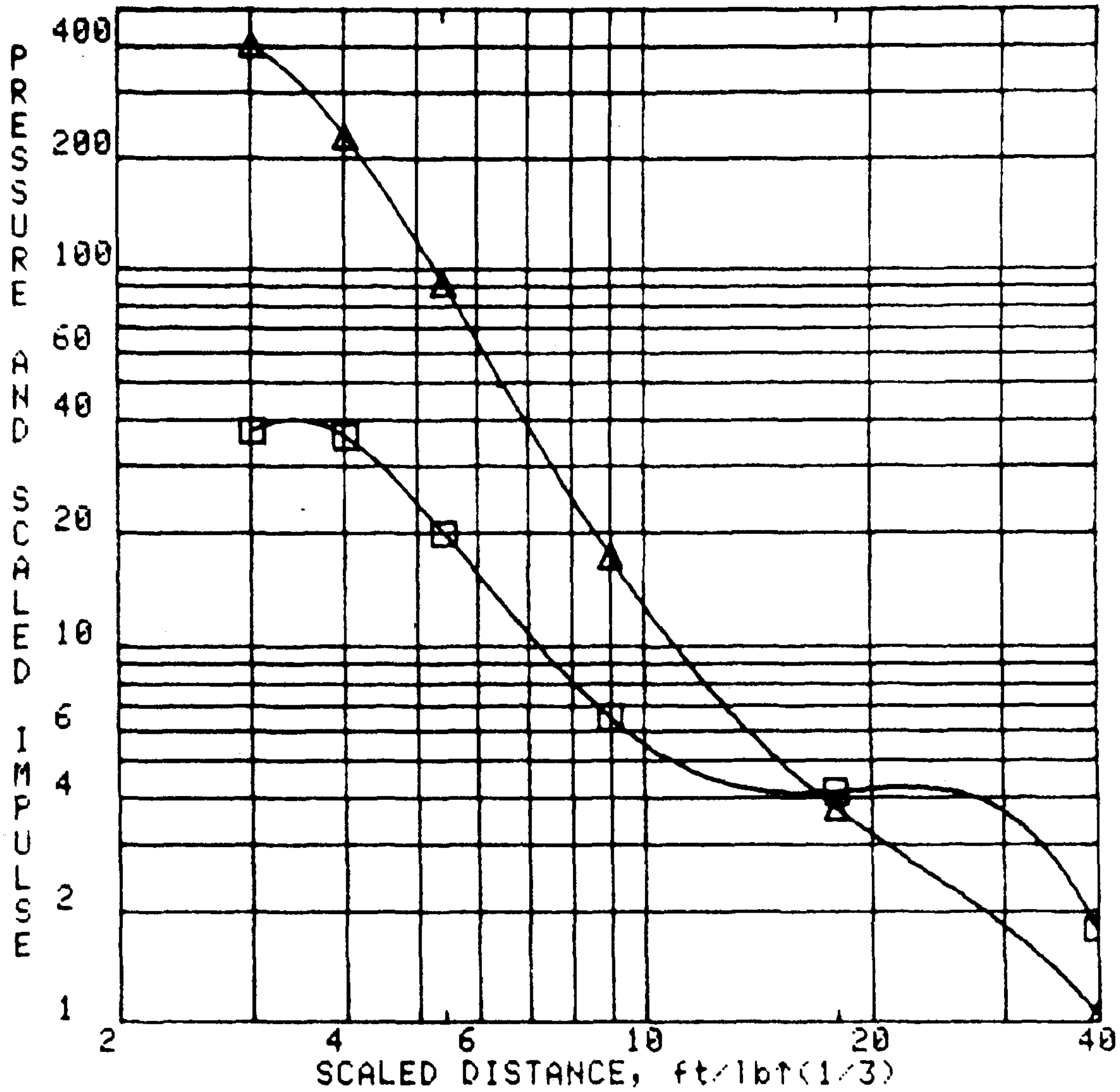


Figure 88. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for Flake TNT in Truncated Prism Configuration, L/D = 2:1.

OBJECTIVE

The objective of this study was to determine the maximum airblast output in terms of peak pressure and positive impulse for lead azide, a primary explosive ,and to compare these values with standard hemispherical TNT data to determine TNT equivalency.

MATERIAL

Dextrinated lead azide a sensitive primary explosive, was detonated in quantities of 0.67, 0.91, and 11.34 kg (1.5, 2, and 25 lb).

TEST SETUP

Wet dextrinated lead azide in a 1.48 kg (1.5 lb) quantity was placed in a 0.95 liter (1 quart) conductive rubber beaker. A 27 g (1 oz) RDX booster charge was placed under the azide sample and initiated. A circular hole was cut out of the bottom of the beaker to accommodate the booster. A thin cheesecloth disc was glued to the inside bottom of the beaker to prevent the test material from escaping. A wooden platform was constructed to position a number 8 blasting cap underthe booster and as a support. The wooden platform, blasting cap, booster, and beaker were positioned at ground zero atop an armor steel plate.

The 0.91 kg (2 lb) dry lead azide tests were conducted in a similar manner.

The 11.34 kg (25 lb) wet lead azide tests were conducted in cheesecloth bags atop a wooden platform to hold the booster and blasting cap placed at ground zero atop a steel armor steel plate. The bag was allowed to shape itself over and around the booster.

INSTRUMENTATION

The instrumentation system used was similar to that described in the chapter entitled "Instrumentation" and descibed in the nitroglycerine instrumentation chapter. A 101.6 mm (4 inch) thick armor plate was located at ground zero Radiating from ground zero were two instrument arrays 90 degrees apar to which the blast transducers were surface mounted. The transducers were located at discrete intervals determined by anticipated blast overpressure.

RESULTS

Individual test results are given in the original test report. Combined results of the 0.91 and 11.34 kg (2 and 25 lb) charge weights are given in Table 41 and Figure 89. The 0.6 kg (1.5 lb) tests were excluded because of the low values, as they would have wrongly influenced the results by producing lower average values.

DISCUSSION

Peak pressure values for the combined results of the 0.91 and 11.34 kg (2 and 25 lb) tests were less than expected at all scaled distances. The pressure values were 238, 138, 91.8, 32.2, 10, and 3.87 kPa (34.52, 20.1, 13.32, 4.67, 1.5, and 0.5 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 0.3, 0.3, 0.3, 0.3, 0.2, and 0.2 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were less than expected at all scaled distances of the experiment. The scaled positive impulse values were 77, 61, 46.9, 30, 15, and 2.9 kPa-ms/kg$^{1/3}$ (8.55, 6.77, 5.23, 3.4, 1.7, and 0.3 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59. 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.3, 0.3, 0.4, 0.4, 0.4, and 0.4 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) Dextrinated Lead Azide when detonated results in peak pressure values which are less than equal amounts of cast hemispherical TNT at all scaled distances between 1.19 and 15.87 m/kg$^{1/3}$ (3.0 and 40.0 ft/lb$^{1/3}$).

(2) Scaled positive impulse values for dextrinated lead Azide are less than equal amounts of cast hemispherical TNT at all scaled distances of the experiment.

(3) Results of the lead azide TNT equivalency tests scaled as functions of the cube root of the charge weights.

Table 41. Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse values for Dextrinated Lead Azide.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	34.52	238.01	8.55	76.76	22.000	8.727	1.14	7.83	1.30	11.69
4.000	1.187	20.10	138.60	6.77	60.76	23.000	9.124	1.07	7.37	1.21	10.89
5.000	1.983	13.32	91.85	5.59	50.15	24.000	9.521	1.01	6.96	1.13	10.14
6.000	2.380	9.57	65.96	4.78	42.87	25.000	9.917	0.96	6.59	1.05	9.44
7.000	2.777	7.26	50.06	4.19	37.61	26.000	10.314	0.91	6.27	0.98	8.78
8.000	3.174	5.74	39.55	3.74	33.60	27.000	10.711	0.87	6.03	0.92	8.29
9.000	3.570	4.67	32.23	3.39	30.43	28.000	11.108	0.83	5.71	0.85	7.59
10.000	3.967	3.90	26.90	3.10	27.81	29.000	11.504	0.79	5.42	0.78	7.04
11.000	4.364	3.32	22.90	2.85	25.59	30.000	11.901	0.76	5.25	0.73	6.54
12.000	4.760	2.87	19.82	2.64	23.66	31.000	12.298	0.73	5.05	0.68	6.06
13.000	5.157	2.52	17.38	2.45	21.95	32.000	12.694	0.71	4.87	0.63	5.64
14.000	5.554	2.24	15.43	2.27	20.41	33.000	13.091	0.68	4.71	0.58	5.21
15.000	5.950	2.01	13.83	2.12	19.01	34.000	13.488	0.66	4.56	0.54	4.82
16.000	6.347	1.81	12.51	1.98	17.73	35.000	13.884	0.64	4.42	0.50	4.46
17.000	6.744	1.65	11.40	1.84	16.54	36.000	14.281	0.62	4.29	0.46	4.12
18.000	7.141	1.52	10.46	1.72	15.43	37.000	14.678	0.61	4.17	0.42	3.81
19.000	7.537	1.40	9.66	1.60	14.40	38.000	15.075	0.59	4.06	0.39	3.52
20.000	7.934	1.30	8.96	1.50	13.44	39.000	15.471	0.57	3.96	0.36	3.25
21.000	8.331	1.21	8.36	1.40	12.53	40.000	15.868	0.56	3.37	0.33	3.00

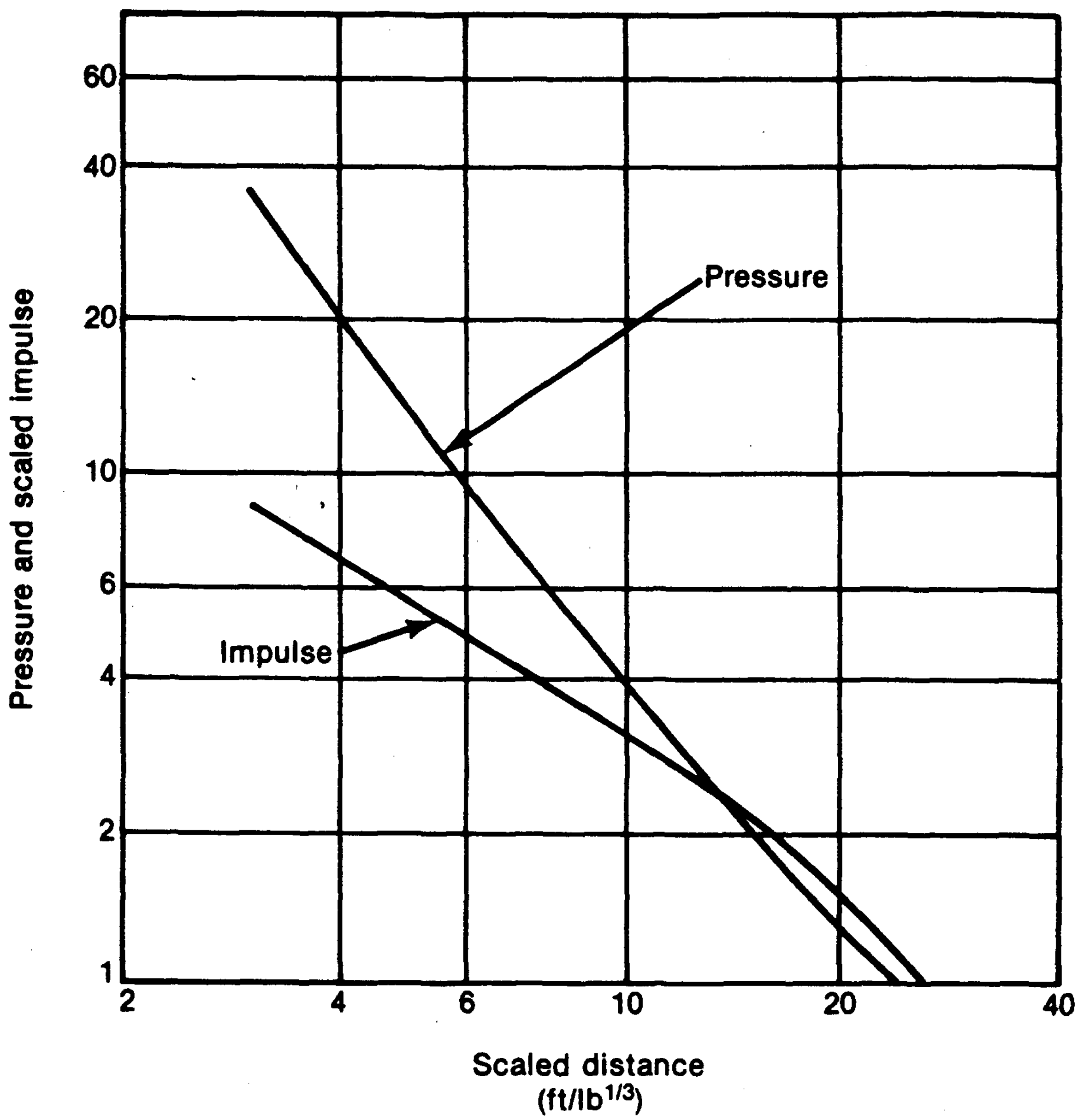


Figure 89. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for Dextrinated Lead Azide.

OBJECTIVE

The objective of this study was to determine the maximum airblast output in terms of peak pressure and positive impulse for lead styphnate and compare these values with hemispherical TNT data to determine TNT equivalency.

MATERIAL

Lead styphnate, a primary explosive, was detonated in nominal quantities of 0.7, 0.9, 11.3 and 68 kg (1.57, 2.0 25 and 150 lb) charge weights.

TEST SETUP

Both wet and dry lead styphnate in 0.7, 0.9 (1.57 and 2.0 lb) quantities were placed in a conductive rubber beaker and a 27 g PBX booster was placed under the sample and initiated. Typical test setup was described in the chapter entitled "Lead Azide".

Quantities ranging from 10.9, 11.2, to 12.4 kg (23.9, 24.7, and 27.3 lb) were placed in cheesecloth bags and initiated by a 81 g PBX booster and a number 8 blasting cap.

Charges of 67.1 and 68 kg (148 and 150 lb), in standard shipping drums, were initiated by using 2.27 kg (5 lb) of Composition C4 in a cube configuration and a number 8 blasting cap.

INSTRUMENTATION

Instrumentation setup was similar to the setup used in the lead azide tests with a detailed description given in the chapter entitled "Instrumentation".

RESULTS

Individual test results are given in the test report. The test results of 0.7, 0.9, 67.1, and 68.0 kg (1.57, 2.0, 148, and 150 lb) are combined and reported in Table 42 and Figure 90. The 11.3 kg (25 lb) results are given separately in Table 43 and Figure 91.

DISCUSSION

The combined peak pressure values were less than expected at all scaled distances of the experiment. The pressure values were 431, 216, 117, 43, 12, and 4.44 kPa (62.50, 31.3, 16.8, 6.2, 1.7, and 0.64 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 0.3, 0.4, 0.3, 0.3, 0.3, and 0.1 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were less than expected at all scaled distances of the experiment. The scaled positive impulse values were 90.6, 70.3, 55.4, 35.4, 17, and 8.07 kPa-ms/kg$^{1/3}$ (10.1, 7.83, 6.17, 3.95, 1.9, and 0.9 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.4, 0.4, 0.4, 0.5, 0.4, and 0.1 times equal amounts of TNT at the same scaled distances, respectively.

Peak pressure values for the 11.3 kg (25 lb) charges were less than expected at all scaled distances of the experiment. The pressure values were 736, 386, 182, 54, 26, and 12.25 kPa (106.7, 56.3, 26.5, 6.0, 2.4, and 0.83 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 0.7, 0.6, 0.6, 0.6, 0.5, and 0.5 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values for the 11.3 kg (25 lb) charge weights were less than expected at all scaled distance of the experiment. The scaled positive impulse values were 139, 114, 88.6, 54.4, 26.4, and 12.4 kPa-ms/kg$^{1/3}$ (15.5, 12.7, 9.88, 6.06, 2.95, and 1.38 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.7, 0.8, 0.7, 0.6, 0.6, and 0.6 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) Peak pressure and scaled positive impulse values were less than equal amounts of TNT at all scaled distances of the experiment.

(2) Pressure and scaled positive impulse values did not scale as a function of the cube root scaling laws as the 11.3 kg (25 lb) charge values were greater than all other charge weights tested.

Table 42. Summary of Results of Hemispherical Surface Bursts, Peak Pressure and Scaled Positive Impulse Values for Lead Styphnate.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	61.46	423.75	10.02	89.91	22.000	8.727	1.41	9.72	1.53	13.70
4.000	1.587	31.99	220.56	7.84	70.31	23.000	9.124	1.32	9.11	1.46	13.07
5.000	1.983	19.77	136.29	6.56	58.87	24.000	9.521	1.24	8.58	1.39	12.50
6.000	2.380	13.56	93.47	5.66	50.81	25.000	9.917	1.17	8.10	1.34	12.00
7.000	2.777	9.97	68.74	4.97	44.61	26.000	10.314	1.11	7.67	1.29	11.54
8.000	3.174	7.70	53.11	4.41	39.61	27.000	10.711	1.06	7.28	1.24	11.12
9.000	3.570	6.18	42.59	3.98	35.48	28.000	11.108	1.00	6.93	1.20	10.75
10.000	3.967	5.10	35.83	3.57	32.01	29.000	11.504	0.97	6.67	1.17	10.54
11.000	4.364	4.30	29.64	3.24	29.07	30.000	11.901	0.92	6.32	1.13	10.10
12.000	4.760	3.69	25.47	2.96	26.56	31.000	12.298	0.88	6.05	1.09	9.82
13.000	5.157	3.22	22.22	2.72	24.39	32.000	12.694	0.84	5.81	1.07	9.57
14.000	5.554	2.85	19.63	2.51	22.16	33.000	13.091	0.81	5.58	1.04	9.34
15.000	5.590	2.54	17.53	2.32	20.86	34.000	13.488	0.78	5.37	1.02	9.14
16.000	6.347	2.29	15.80	2.16	19.43	35.000	13.884	0.75	5.18	1.00	8.95
17.000	6.744	2.08	14.35	2.02	18.16	36.000	14.281	0.73	5.00	0.98	8.78
18.000	7.141	1.90	13.13	1.90	17.05	37.000	14.678	0.70	4.84	0.96	8.63
19.000	7.537	1.75	12.09	1.79	16.06	38.000	15.075	0.68	4.68	0.95	8.49
20.000	7.934	1.62	11.19	1.69	15.18	39.000	15.471	0.66	4.54	0.93	8.37
21.000	8.331	1.51	10.40	1.60	14.40	40.000	15.868	0.64	4.40	0.92	8.26

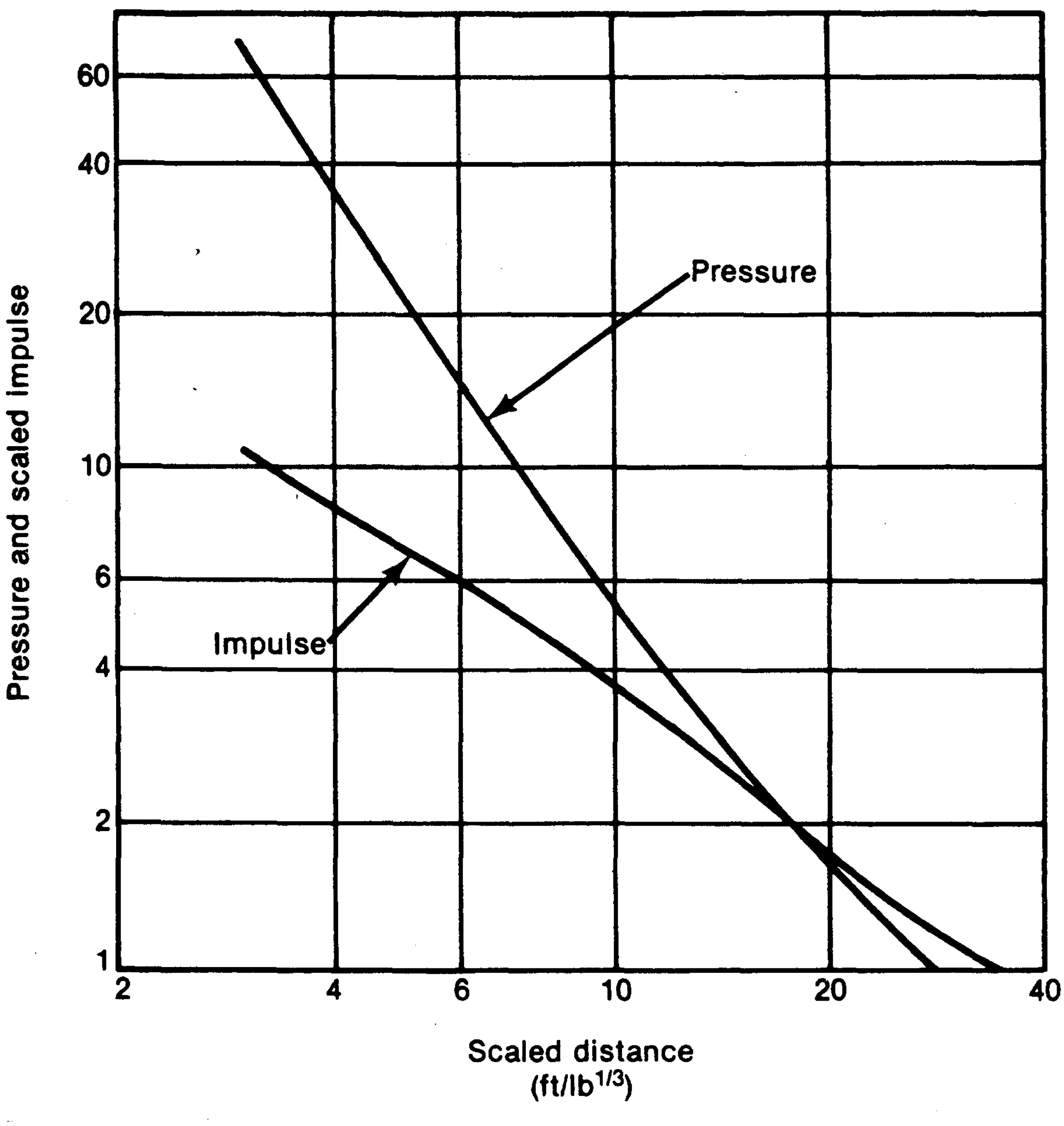


Figure 90. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for Lead Styphnate.

Table 43. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse Values for Lead Styphnate 11.3 kg (25 lb).

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	106.75	736.03	15.46	138.71	22.000	8.727	1.88	12.95	2.40	21.55
4.000	1.587	56.03	386.31	12.67	113.66	23.000	9.124	1.78	12.25	2.30	20.61
5.000	1.983	32.29	222.64	10.57	94.82	24.000	9.521	1.68	11.62	2.20	19.76
6.000	2.380	20.53	141.53	8.98	80.62	25.000	9.917	1.60	11.04	2.11	18.98
7.000	2.777	14.16	92.60	7.77	69.72	26.000	10.314	1.52	10.51	2.04	18.40
8.000	3.174	10.41	71.79	6.82	61.18	27.000	10.711	1.45	10.12	1.96	17.61
9.000	3.570	8.06	55.44	6.06	54.36	28.000	11.108	1.39	9.57	1.90	17.01
10.000	3.967	6.49	44.73	5.44	48.81	29.000	11.504	1.33	9.15	1.83	16.45
11.000	4.364	5.39	37.18	4.93	44.23	30.000	11.901	1.27	8.75	1.78	15.94
12.000	4.760	4.60	31.70	4.50	40.39	31.000	12.298	1.22	8.38	1.72	15.46
13.000	5.157	4.00	27.60	4.14	37.15	32.000	12.694	1.16	8.03	1.67	15.01
14.000	5.554	3.54	24.43	3.83	34.37	33.000	13.091	1.12	7.69	1.63	14.60
15.000	5.950	3.18	21.93	3.56	31.98	34.000	13.488	1.07	7.37	1.58	14.21
16.000	6.347	2.89	19.90	3.33	29.89	35.000	13.884	1.03	7.07	1.54	13.85
17.000	6.744	2.65	18.24	3.13	28.06	36.000	14.281	0.98	6.78	1.51	13.51
18.000	7.141	2.44	16.84	2.95	26.45	37.000	14.678	0.94	6.50	1.49	13.20
19.000	7.537	2.27	15.66	2.79	25.02	38.000	15.075	0.90	6.23	1.44	12.90
20.000	7.934	2.12	14.64	2.64	23.73	39.000	15.471	0.87	5.98	1.41	12.67
21.000	8.331	1.99	13.74	2.52	22.81	40.000	15.868	0.83	5.73	1.38	12.35

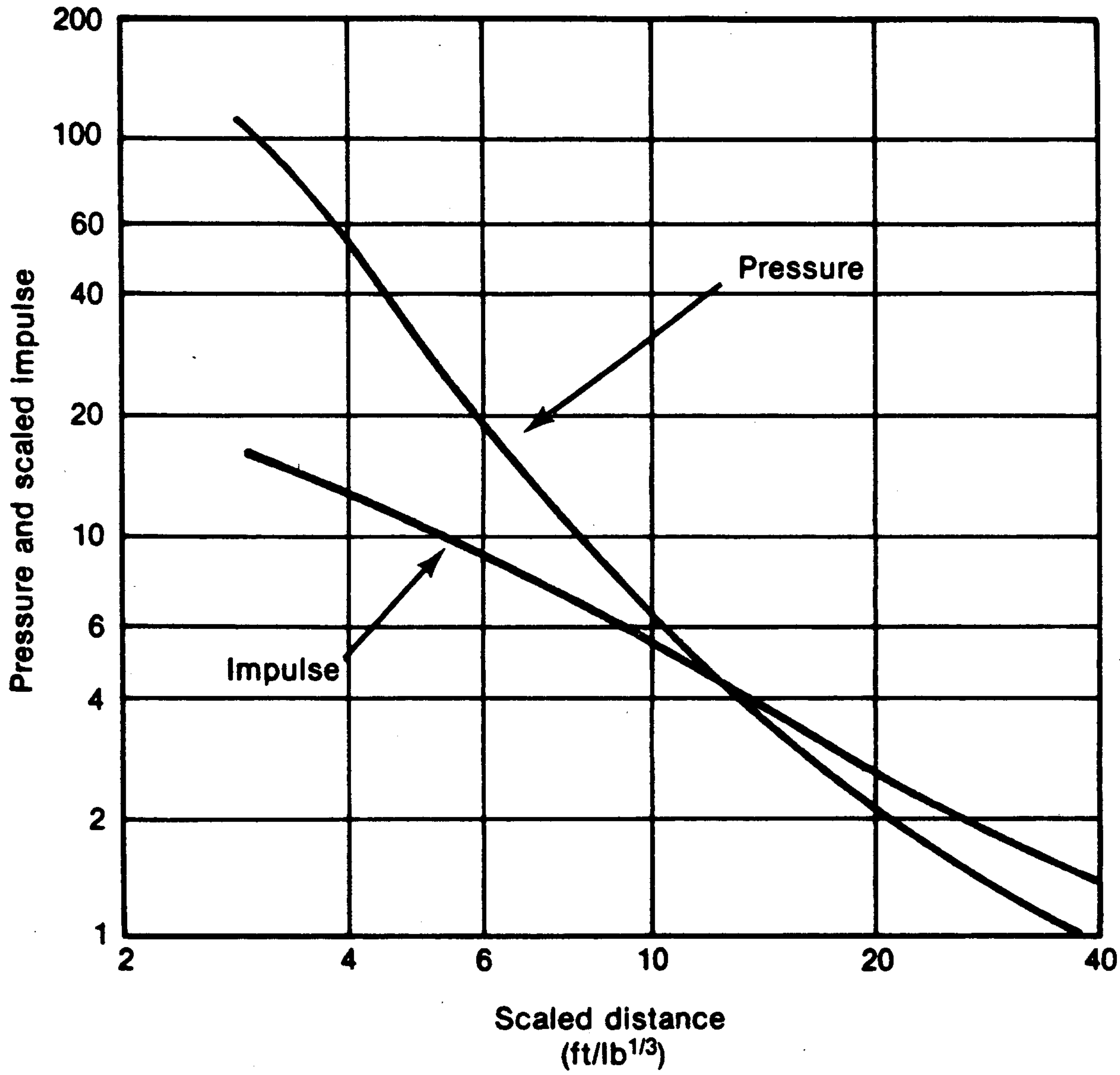


Figure 91. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for Lead Styphnate 11.3 kg (25 lb).

OBJECTIVE

The objective of this study was to determine the maximum airblast output, peak pressure and positive impulse for tetracene by comparing these values to hemispherical TNT data to determine equivalency.

MATERIAL

Tetracene, a primary explosive, was detonated in beakers, a dry state, and in storage bags in a wet state.

TEST SETUP

Tests were conducted on 0.3 kg (0.65 lb) quantities of tetracene in a conductive rubber beaker. A circular hole was cut out of the bottom of the beaker to accommodate the PBX booster and the blasting cap. The initiating train was supported by a wooden platform. The beaker, and platform with booster charge were placed at ground zero atop an armor steel witness plate.

The 4.5 kg (10 lb) tests were conducted in wet cheesecloth bags containing the tetracene placed atop a wooden base plate and booster. The bag was allowed to shape itself over the booster charge. The bag, booster, and wooden base were placed atop an armor steel plate.

INSTRUMENTATION

The instrumentation system used was similar to that described in the chapter entitled "Instrumentation". A 101.6 mm (4 inch) thick armor plate was located at ground zero. Radiating from this point were two 6.1 m (20 foot) wide by 30 m (100 foot) long runways, 90 degrees apart, covered and leveled with a 50.8 to 101.6 mm (2 to 4 inch) thick layer of sand.

Pressure gages were located at descrete intervals in the cleared areas of the test site. The gages were flush-mounted in steel plates which in turn were flush-mounted with the ground surface. Determination of the locale of a particular gage was based upon the anticipated over-pressure.

RESULTS

The pressure and scaled positive impulse values of all charge weight were combined for stastistical validity. The results are given in Table 44 and Figure 92.

DISCUSSION

Peak pressure values were less than expected at all scaled distances of the experiment. The pressure values were 171, 110, 68.05, 30.6, 12, and 4.6 kPa (24.9, 15.95, 9.87, 4.44, 1.7, and 0.83 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These values equate to 0.1, 0.1, 0.2, 0.2, 0.2, and 0.3 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were less than expected at all scaled distances of the experiment. The scaled positive impulse values were 65.9, 54.3, 44.9, 30.6, 15.1, and 6.6 kPa-ms/kg$^{1/3}$ (7.35, 6.05, 5.00, 3.41, 1.69, and 0.73 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.2, 0.2, 0.2, 0.3, 0.3, and 0.2 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) Peak pressure and scaled positive impulse values were less than expected at all scaled distances of the experiments.

(2) To within experimental limits, blast pressure and impulse scaled as a cube root function of the charge weight.

Table 44. Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse Values for Tetracene, L/D = 1:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	24.90	171.71	7.35	65.94	22.000	8.727	1.33	9.15	1.34	12.06
4.000	1.587	15.95	110.00	6.05	54.33	23.000	9.124	1.26	8.68	1.28	11.46
5.000	1.983	11.17	76.99	5.25	47.14	24.000	9.521	1.20	8.25	1.22	10.92
6.000	2.380	8.34	57.50	4.65	41.76	25.000	9.917	1.14	7.87	1.16	10.43
7.000	2.777	6.54	45.06	4.17	37.39	26.000	10.314	1.09	7.51	1.10	9.90
8.000	3.174	5.31	36.62	3.76	33.72	27.000	10.711	1.04	7.19	1.07	9.58
9.000	3.570	4.44	30.61	3.41	30.57	28.000	11.108	1.00	6.90	1.03	9.20
10.000	3.967	3.80	26.17	3.10	27.85	29.000	11.504	0.96	6.63	0.99	8.93
11.000	4.364	3.30	22.79	2.84	25.48	30.000	11.901	0.93	6.38	0.96	8.61
12.000	4.760	2.92	20.13	2.61	23.41	31.000	12.298	0.89	6.15	0.92	8.26
13.000	5.157	2.61	18.01	2.41	21.58	32.000	12.694	0.86	5.93	0.89	8.00
14.000	5.554	2.36	16.27	2.23	19.97	33.000	13.091	0.83	5.73	0.86	7.75
15.000	5.950	2.15	14.84	2.07	18.55	34.000	13.488	0.80	5.54	0.84	7.53
16.000	6.347	1.98	13.63	1.93	17.29	35.000	13.884	0.78	5.36	0.82	7.32
17.000	6.744	1.83	12.60	1.80	16.16	36.000	14.281	0.75	5.20	0.79	7.13
18.000	7.141	1.76	11.72	1.69	15.16	37.000	14.678	0.73	5.01	0.78	6.96
19.000	7.537	1.59	10.95	1.59	14.26	38.000	15.075	0.71	4.98	0.76	6.80
20.000	7.934	1.49	10.27	1.50	13.45	39.000	15.471	0.69	4.75	0.74	6.65
21.000	8.331	1.40	9.68	1.42	12.72	40.000	15.868	0.67	4.62	0.73	6.51

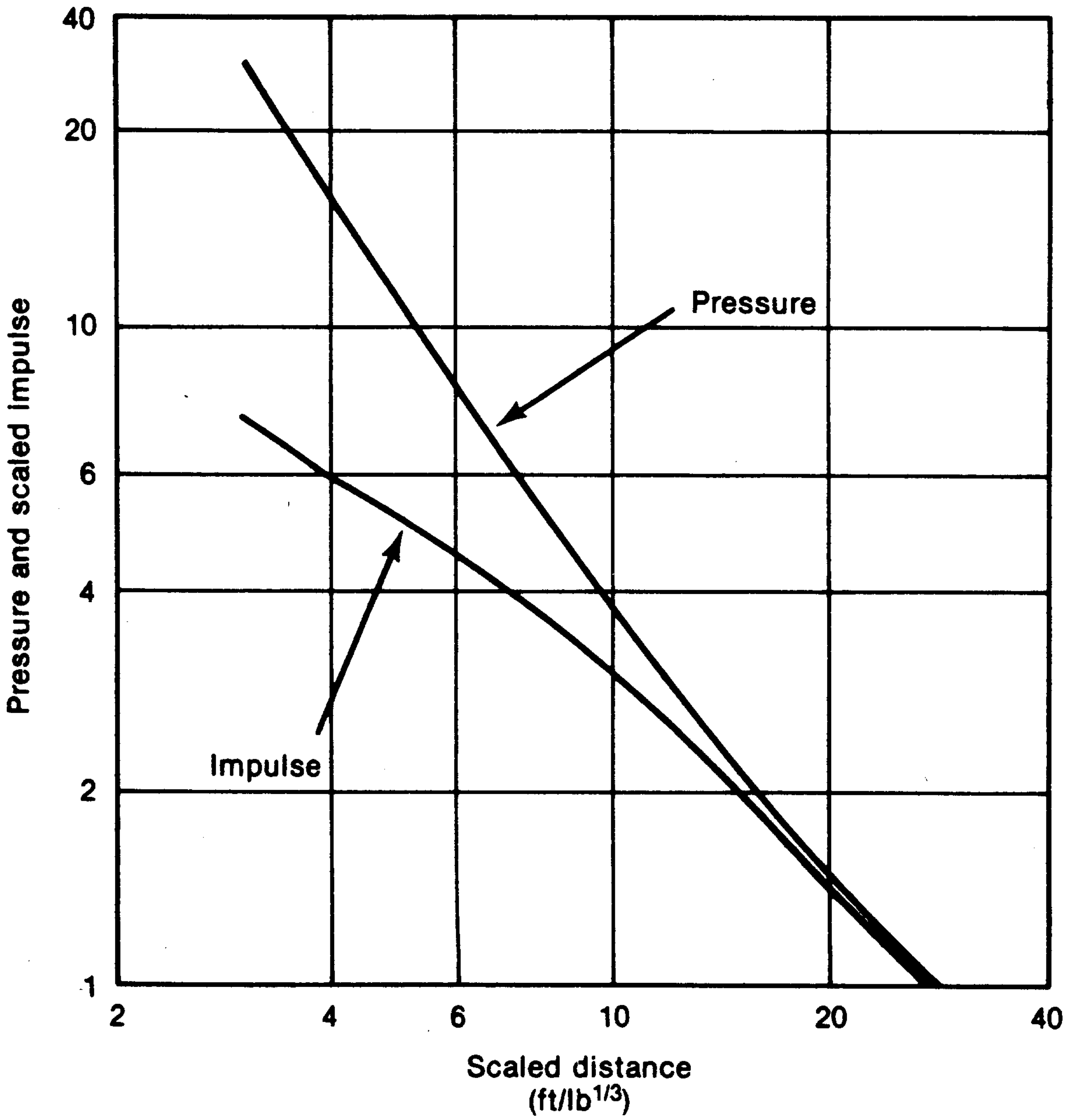


Figure 92. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for Tetracene, L/D = 1:1.

M42 GRENADE TRAY
155 MM M483 PROJECTILE[21]

OBJECTIVE

The objective of this study was to determine the maximum output from the detonation of a single M483 155 mm Projectile and in-processs configuration of a tray of 64 M42 grenades in terms of airblast overpressure and positive impulse.

MATERIALS

The M483 155 mm ICM is loaded with eight layers of each with eight M42 grenades, and three layers of eight each M46 grenades for a total of 88 submunitions. Each grenade (submunition) is filled with 30 g (0.066 lb) of Composition A5 explosive. The total explosive weight is 2.64 kg (5.8 lb).

TEST SETUP

Airblast output was evaluated for the projectile filled with the 88 submunitions and expelling charge and a single in-process tray of 64 submunitions. Physical characteristics of the test charges are described as follows:

(1) A plywood tray filled with 64 M42 unfuzed grenades was placed on a steel witness plate and a single grenade was initiated by a J2 engineer's special blasting cap. Four tests were conducted in this configuration.

(2) A single full up M483, 155 mm was placed vertically with the nose pointed downward on a steel witness plate. A hole slightly smaller than the diameter of the round was cut in the witness plate to allow the nose cavity to protrude into the ground approximately 20.3 cm (8 inches). The projectile was primed after removing both the M10 expulsion charge and the most centrally located grenade in the top layer and replacing them with an unfuzed M42 grenade. The unfuzed grenade was initiated by a J2 engineer's blasting cap.

INSTURMENTATION

Twelve side-on pressure transducers were mounted flush to the surface in two sand-filled runways in a 90 degree array. Distances from the charge to the transducers ranged from 1.64 to 23.95 m (5 to 73 ft) and remained constant throughout the test series.

RESULTS

Test results of the tray of 64 submunitions are given in Table 45 and Figure 93. The single projectile are given in Table 46 and Figure 94.

DISCUSSION

Pressure values for the tray of 64 sub-munitions were less than expected at scaled distances of 2.14 $m/kg^{1/3}$ (5.4 $ft/lb^{1/3}$)and equal to or greater than expected at scaled distances equal to or greater than 3.57$m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$). The pressure values were 630, 249, 138, 75, 32, and 8.8 kPa (91.3, 36.1, 20.0, 10.8, 4.57, and 1.27 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 0.6, 0.4, 0.5, 1.0, 1.7, and 1.2 times equal amounts of TNT at the same scaled distance, respectively. Scaled positive impulse values were equal to or less than expected at all scaled distances of the experiment. The scaled positive impulse values were 101, 86, 78, 64, 36, and 14.4 kPa-$ms/kg^{1/3}$ (11.35, 9.63, 8.74, 7.18, 3.97, and 1.61 psi-$ms/kg^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1\cdot 3}$), respectively. These scaled positive impulse values equate to 0.5, 0.5, 0.7, 0.8, 1.0, and 0.8 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the M483 projectile were less than expected at a scaled distance of 1.19 $m/kg^{1/3}$ (3.0 $ft/lb^{1/3}$) and greater than expected at scaled distances equal to or greater than 1.59 $m/kg^{1/3}$ (4.0 $ft/lb^{1/3}$). The pressure values were 839, 486, 282, 112, 32, and 10 kPa (121.7, 70.47, 40.84, 16.21, 4.62, and 1.46 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 0.7, 1.1, 1.1, 1.6, 1.7, and 1.6 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were equal to or greater than expected at scaled distances equal to or less than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$) and less than expected at scaled distances equal to or greater than 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$). The scaled positive impulse values were 188, 154, 115, 66, 29, and 11.1 kPa-$ms/kg^{1/3}$ (20.98, 16.87, 12.83, 7.41, 3.22, and 1.24 psi-$ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 1.1, 1.2, 1.1, 1.0, 0.7, and 0.5 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) The pressure values for the tray containing 64 M42 grenades were less than expected at scaled distances equal to or less than 2.14 $m/kg^{1/3}$ (5.4 $ft/lb^{1/3}$) and greater than expected at scaled distances equal to or greater than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$).

(2) Scaled positive impulse values for the tray containing 64 M42 grenades were less than expected at all scaled distances of the experiment.

(3) Peak pressure for the M483, 155 mm projectile tests was less than expected at a scaled distance of 1.19 $m/kg^{1/3}$ (3.0 $ft/lb^{1/3}$) and greater than expected at scaled distances

equal to or greater than 1.59 m/kg$^{1/3}$ (4.0 ft/lb$^{1/3}$).

(4) Scaled positive impulse for the M483, 155 mm projectile was greater than expected at scaled distances equal to or less than 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$) and less than expected at scaled distances equal to or greater than 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$).

(5) Pressure and scaled positive impulse values were significantly less than equal amounst of cylindrical Composition A5.

(6) The reduction of pressure and scaled positive impulse values was due to the energy required to burst the projectile and/or the grenade.

Table 45. Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse Values for 64, M42 Grenades in In-process Configuration

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{\text{psi} \cdot \text{ms}}{\text{lb}^{1/3}}$	Scaled Impulse $\frac{\text{kPa} \cdot \text{ms}}{\text{kg}^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{\text{psi} \cdot \text{ms}}{\text{lb}^{1/3}}$	Scaled Impulse $\frac{\text{kPa} \cdot \text{ms}}{\text{kg}^{1/3}}$
3.000	1.190	91.28	629.37	11.35	101.86	22.000	8.727	3.33	22.95	3.14	28.14
4.000	1.587	36.14	249.17	9.63	86.39	23.000	9.124	3.09	21.32	2.97	26.67
5.000	1.983	22.70	156.48	8.93	80.18	24.000	9.521	2.88	19.86	2.82	25.32
6.000	2.380	17.21	118.65	8.47	76.02	25.000	9.917	2.69	18.54	2.68	24.09
7.000	2.777	14.23	98.08	8.05	71.21	26.000	10.314	2.52	17.35	2.56	22.97
8.000	3.174	12.27	84.64	7.62	68.36	27.000	10.711	2.36	16.28	2.45	21.95
9.000	3.570	10.83	74.70	7.18	64.45	28.000	11.108	2.22	15.31	2.34	21.01
10.000	3.967	9.68	66.76	6.75	60.54	29.000	11.504	2.09	14.43	2.25	10.16
11.000	4.364	8.72	60.11	6.32	56.72	30.000	11.901	1.98	13.64	2.16	19.38
12.000	4.760	7.89	54.38	5.91	53.05	31.000	12.298	1.87	12.92	2.08	18.67
13.000	5.157	7.16	49.37	5.52	49.58	32.000	12.694	1.78	12.26	2.01	18.02
14.000	5.554	6.52	44.93	5.16	46.33	33.000	13.091	1.69	11.67	1.94	17.42
15.000	5.950	5.95	40.99	4.83	43.32	34.000	13.488	1.61	11.13	1.88	16.88
16.000	6.347	5.44	37.48	4.52	40.54	35.000	13.884	1.54	10.63	1.83	16.38
17.000	6.744	4.98	34.34	4.23	37.98	36.000	14.281	1.48	10.19	1.77	15.91
18.000	7.141	4.57	31.54	3.97	35.64	37.000	14.678	1.42	9.78	1.73	15.51
19.000	7.537	4.21	29.03	3.73	33.50	38.000	15.075	1.36	9.40	1.69	15.13
20.000	7.934	3.88	26.78	3.52	31.55	39.000	15.471	1.31	9.06	1.65	14.79
21.000	8.331	3.59	24.76	3.32	29.77	40.000	15.868	1.27	8.75	1.61	14.47

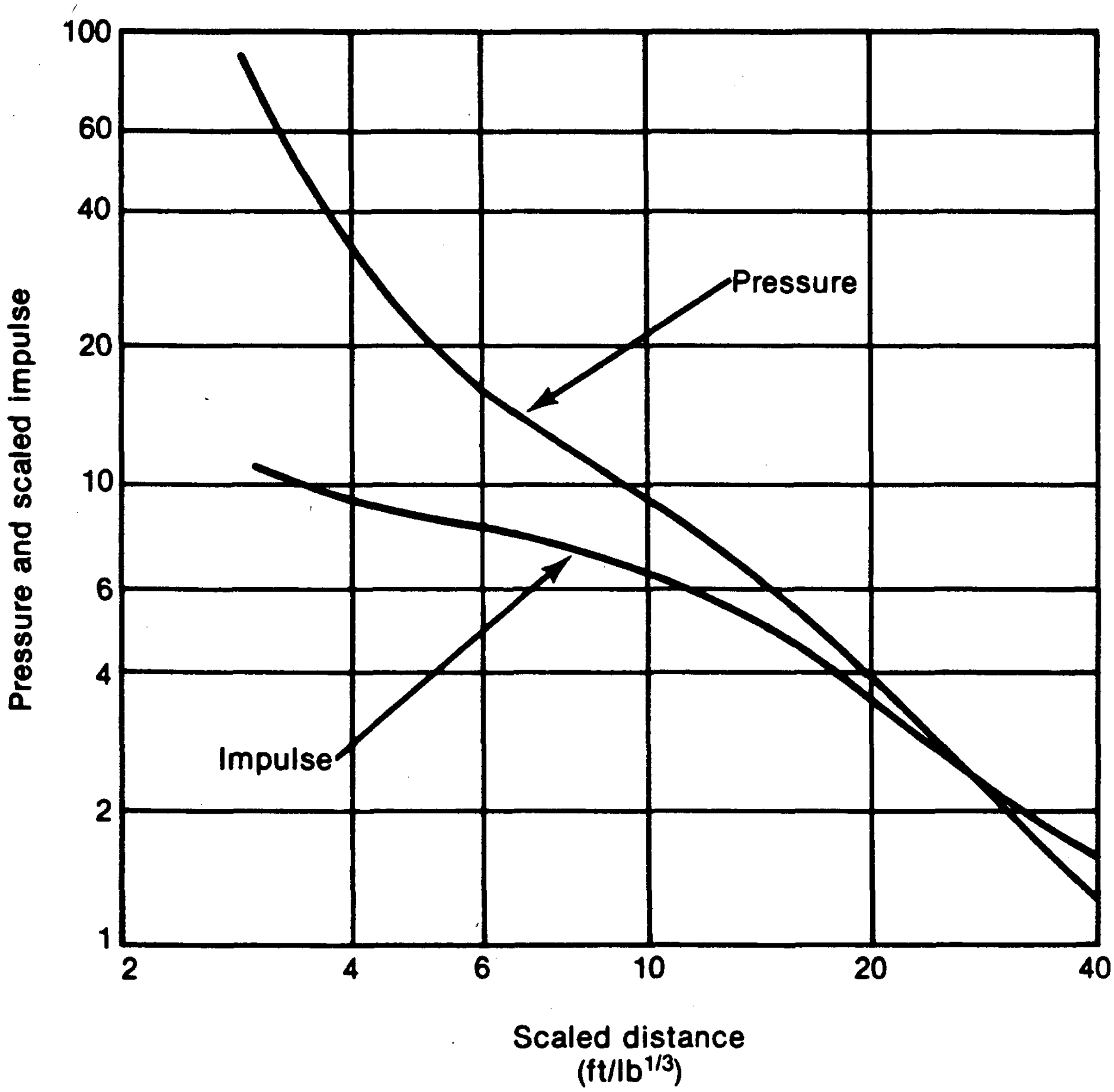


Figure 93. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for 64, M42 Grenades in In-Process Configuration.

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Table 46. Summary of Results for Hemispherical Surface Bursts, Peak Pressure; and Scaled Positive Impulse Values for M483, 155 mm, ICM Projectile.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	121.69	839.04	20.98	188.31	22.000	8.727	3.28	22.63	2.52	22.59
4.000	1.587	70.47	485.92	16.89	151.57	23.000	9.124	3.05	21.05	2.38	21.40
5.000	1.983	46.92	323.52	13.83	124.08	24.000	9.521	2.85	19.66	2.26	20.32
6.000	2.380	33.78	232.89	11.54	103.58	25.000	9.917	2.68	18.45	2.16	19.34
7.000	2.777	25.58	176.36	9.81	88.03	26.000	10.314	2.52	17.37	2.06	18.45
8.000	3.174	20.08	138.46	8.47	75.98	27.000	10.711	2.38	16.42	1.96	17.63
9.000	3.570	16.21	111.75	7.41	66.46	28.000	11.108	2.26	15.57	1.88	16.88
10.000	3.967	13.37	92.18	6.55	58.80	29.000	11.504	2.15	14.81	1.80	16.19
11.000	4.364	11.23	77.42	5.85	52.53	30.000	11.901	2.05	14.13	1.73	15.55
12.000	4.760	9.58	66.03	5.28	47.34	31.000	12.298	1.96	13.52	1.67	14.96
13.000	5.157	8.27	57.05	4.79	42.98	32.000	12.694	1.88	12.97	1.61	14.41
14.000	5.554	7.23	49.85	4.38	39.28	33.000	13.091	1.81	12.48	1.55	13.90
15.000	5.950	6.38	44.01	4.02	36.11	34.000	13.488	1.74	12.03	1.50	13.43
16.000	6.347	5.68	39.19	3.72	33.37	35.000	13.884	1.69	11.62	1.45	12.99
17.000	5.744	5.10	35.19	3.45	30.98	36.000	14.281	1.63	11.25	1.40	12.57
18.000	7.141	4.62	31.82	3.22	28.88	37.000	14.678	1.58	10.92	1.36	12.18
19.000	7.537	4.20	28.97	3.01	27.03	38.000	15.075	1.54	10.62	1.32	11.82
20.000	7.934	3.85	26.54	2.83	25.38	39.000	15.471	1.50	10.34	1.28	11.47
21.000	8.331	3.54	24.44	2.66	23.91	40.000	15.868	1.46	10.09	1.24	11.15

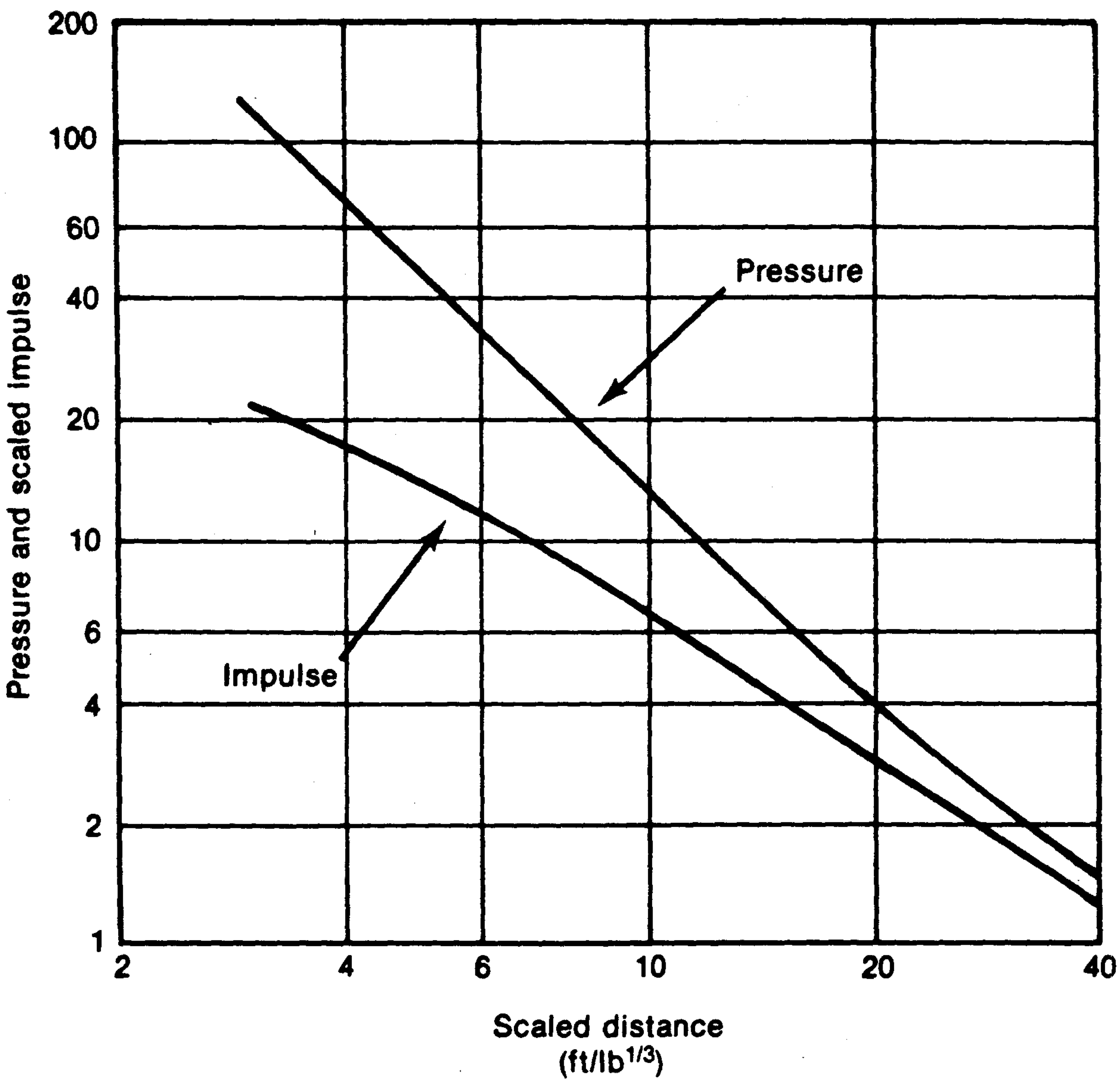


Figure 94. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for the M483, 155 mm, ICM, Projectile.

155MM, AT, M718/741 RAAM PROJECTILE[22]

OBJECTIVE

The objective of this study was to provide data relative to the tendency of the 155 mm, AT, M718/741 RAAM projectiles to mass detonate singluarly, two or more at a time, and in a pallet of eight projectiles.

MATERIAL

Complete projectiles, 155 mm, AT, M718/741 with 9 RAAM mines each containing 0.6 kg (1.26 lb) of high explosive and a dummy electronic lens assembly, were manufactured for this test series.

TEST SETUP

The original test setup was configured for a single projectile test (Single Package Test), three rounds (Stack Test), and a pallet of eight projectiles were placed atop a steel crib surrounded by scrap lumber (External Fire, Stack Test) as outlined in DODESB Explosives Hazard Classification Procedure, US Army Technical Bulletin 700-2, chapter 5, paragraph 5.3: TESTS REQUIRED BY STANAG 4123, AND DEPARTMENT OF DEFENSE FOR STORAGE HAZARD CLASSIFICATION[2].

INSTRUMENTATION

A total of 12 piezoelectric side-on pressure transducers were mounted flush to the ground in a 90-degree array. Distance from the center of the charges corresponded to scaled distances of 3.08, 2.48, 3.43, 4.98, 16.15, and 27.29 m/kg$^{1/3}$ (5.25, 6.26, 8.64, 12.55, 40.7, and 68.8 ft/lb$^{1/3}$). Expected pressures were 207, 138, 69. 35, 7, and 3.4 kPa (03, 20, 10, 5, 1, and 0.5 psi). The instrumentation was set up in accordance with chapter 6, INSTRUMENTATION AND INTREPRETATION OF RESULTS, US Army Technical Bulletin 700-2, September 1982[2].

RESULTS

Individual results are given in the individual test report. The results from all three test configurations were combined for statistical validity due to the limited number of tests. The combined values are given in Table 47 and Figure 95.

DISCUSSION

Peak pressure values for the 155 mm, AT, M718/741, RAAM, Projectile were equal to expected values at scaled distances equal to or less than 2.14 m/kg$^{1/3}$ (5.4 ft/lb$^{1/3}$) and less than expected at scaled distances equal to or greater than 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. The pressure values were 914, 472, 237, 73, 15, and 2.4 kPa (132.5, 68.5, 34.4, 10.64, 2.17, and 0.35 psi), respectively. These pressure values equate to 1.0, 1.0, 1.0, 0.9, 0.4, and 0.1 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were greater than expected at a scaled distance of 1.19 m/kg$^{1/3}$ (3.0 ft/lb$^{1/3}$) and less than expected at all other scaled distances. The scaled positive impulse values were 214, 124, 70, 22, 7.1, and 1.52 kPa-ms/kg$^{1/3}$ (23.9, 13.8, 7.8, 2.42, 0.79, and 0.17 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 1.4, 0.9, 0.5, 0.2, 0.1, and 0.1 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) Peak pressure and scaled positive impulse values scaled as a function of cube root scaling laws.

(2) Peak pressure was equal to the expected values at scaled distances equal to or less than 2.14 m/kg$^{1/3}$ (5.4 ft/lb$^{1/3}$), and less than expected values at scaled distances equal to or greater than 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$).

(3) Scaled positive impulse values were greater than expected at a scaled distance of 1.19 m/kg$^{1/3}$ (3.0 ft/lb$^{1/3}$) and less than expected at all other scaled distances of the experiment.

(4) The low pressure and scaled positive impulse values were attributed to the bursting of the RAAM cases and the projectile casing.

Table 47. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse Values for 155 mm, AT, M718/741, RAAM, Projectile.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	132.52	913.71	23.85	213.99	22.000	8.727	1.37	9.43	0.54	4.84
4.000	1.587	68.46	472.06	13.08	123.83	23.000	9.124	1.23	8.51	0.50	4.45
5.000	1.983	41.02	282.83	9.03	81.01	24.000	9.521	1.12	7.72	0.46	4.10
6.000	2.380	26.99	186.10	6.38	57.28	25.000	9.917	1.02	7.03	0.42	3.80
7.000	2.777	18.95	132.64	4.76	42.73	26.000	10.314	0.93	6.42	0.39	3.52
8.000	3.174	13.94	96.15	3.69	33.15	27.000	10.711	0.85	5.89	0.37	3.28
9.000	3.570	10.64	73.37	2.95	26.50	28.000	11.108	0.79	5.42	0.34	3.06
10.000	3.967	8.35	57.61	2.42	21.69	29.000	11.504	0.73	5.00	0.32	2.86
11.000	4.364	6.71	46.29	2.02	18.09	30.000	11.901	0.67	4.63	0.30	2.69
12.000	4.760	5.50	37.91	1.71	15.33	31.000	12.298	0.62	4.29	0.28	2.52
13.000	5.157	4.57	31.54	1.47	13.17	32.000	12.694	0.58	3.99	0.26	2.38
14.000	5.554	3.86	26.61	1.27	11.44	33.000	13.091	0.54	3.72	0.25	2.24
15.000	5.950	3.29	22.71	1.12	10.03	34.000	13.488	0.50	3.47	0.24	2.12
16.000	6.347	2.84	19.58	0.99	8.87	35.000	13.884	0.47	3.25	0.22	2.00
17.000	6.744	2.47	17.04	0.88	7.91	36.000	14.281	0.44	3.04	0.21	1.90
18.000	7.141	2.17	14.94	0.79	7.09	37.000	14.678	0.41	2.86	0.20	1.80
19.000	7.537	1.91	13.20	0.71	6.40	38.000	15.075	0.39	2.69	0.19	1.71
20.000	7.934	1.70	11.73	0.65	5.81	39.000	15.471	0.37	2.53	0.18	1.63
21.000	8.331	1.52	10.49	0.59	5.29	40.000	15.868	0.35	2.39	0.17	1.55

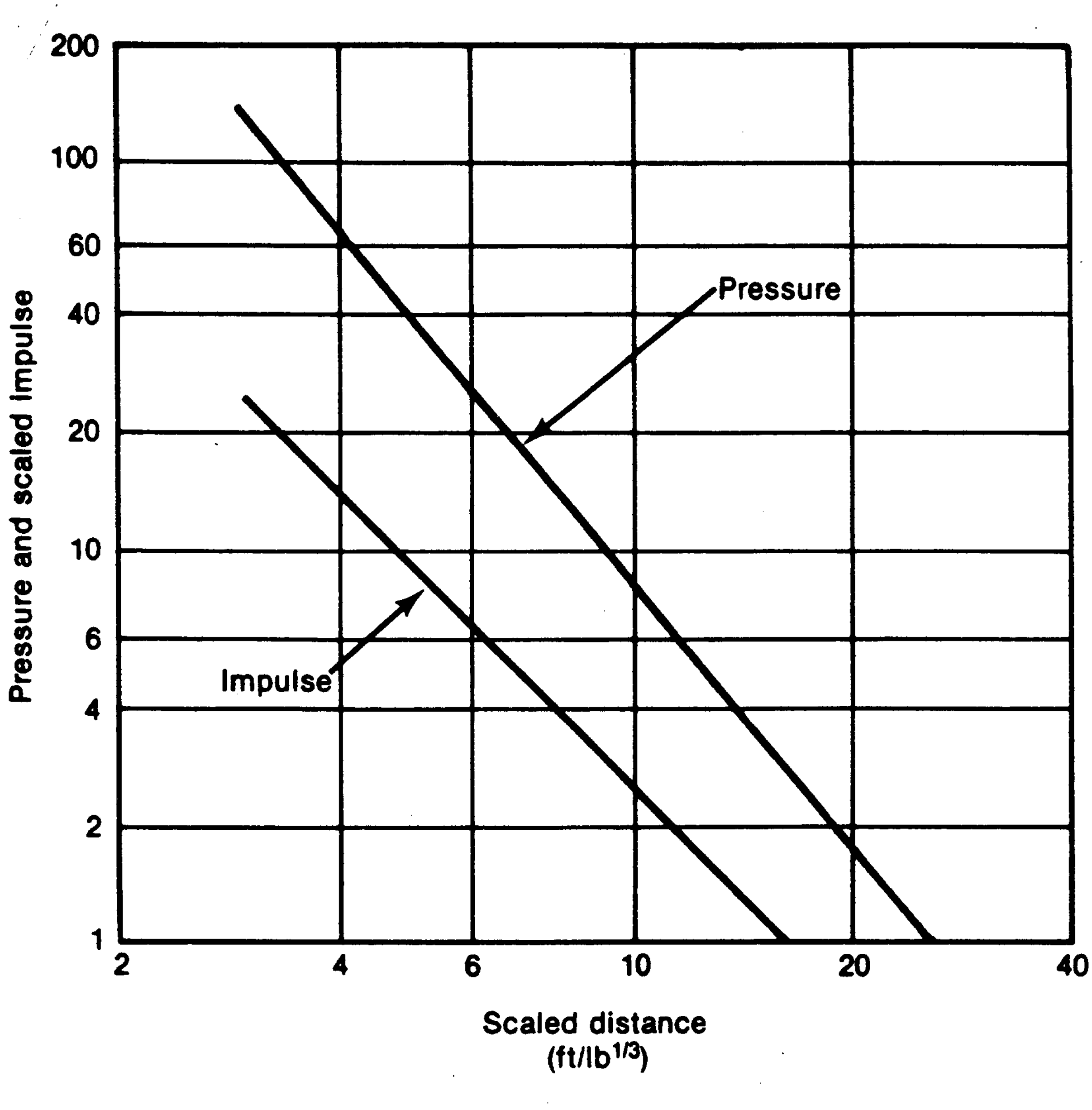


Figure 95. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for 155 mm, AT, M718/741, RAAM, Projectile.

SUMMARY OF EXPLOSIVES AND END ITEMS

A total of 18 bulk explosives and 3 end-items were tested. The bulk explosives were single compounds and binary explosives, including both noninitiating and primary-initiating type explosives. They were tested in 5 different geometries, 10 different physical characteristics, 11 different configurations and 14 different length-to-diameter ratios. The geometries were hemispherical, spherical, cylindrical, orthorhombic, and truncated prisms. These geometries represented shipping containers, dryer beds, thermal dehydration units, transfer boxes, nutsches, powder barrels, hoppers, press-die configurations, storage bins, bags, and test charges. The physical characteristics of the explosives were dry powder, cast explosives, plastic, powder wet with alcohol, chips, flaked, extruded rod, pressed billets, liquid, and a slurry. Length-to-diameter ratios varied from 0.1:1 to 30:1. Each of these factors had a significant effect on the measured blast pressure and positive impulse. The significance of these effects is that they represent in-process and shipping configurations where reflected and side-on pressure and impulse are coalaesced to represent higher values than would be found in pure scientific experiments.

The effects of geometry were most notable with higher impulse and pressure values at close-in scaled distances equal to or less than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$). Length-to-diameter ratios affected pressure and scaled positive impulse values as well. Pressure and scaled positive impulse values were generally greater for the orthorhombic containers with a length-to-diameter ratio equal to or less than 1:1 and equal to or greater than 0.5:1 than either cylindrical, hemispherical and/or spherical charges at scaled distances equal to or less than 2.14 $m/kg^{1/3}$ (5.4 $ft/lb^{1/3}$). Pressure and impulse values were generally higher for cylindrical containers with length-to-diameter ratios equal to or greater than 1:1 at scaled distances equal to or greater than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$). Scaled positive impulse values were affected the most at scaled distances equal to or greater than 2.14 to 7.14 $m/kg^{1/3}$ (5.4 to 18.0 $ft/lb^{1/3}$).

Physical characteristics had the least effect on the measured values. There was no significant difference between flake, chips, dry powder or powder wet with alcohol. Density of the extruded rod and extruded demolition blocks did, however, have higher pressure and impulse values than explosives tested at their apparent bulk densities. Cast charges had less scatter of data,

The effects of the different configurations were most notable for pressure and impulse when metal containers were used in the experiments. Fragmentation from steel or aluminum containers affected the measurements by multiple peaks. Strong confinement, as in end-item munitions, caused reduced pressures and impulses due to the energy required to fragment the case. Light confinement can cause an increase in pressure and impulse[23]. Also, it is possible for light metals and alloys to react with the explosive material and actually increase the pressure and impulse values.

The effect of length-to-diameter ratio (L/D) was significant for both peak pressure and scaled positive impulse. When the L/D ratio varied by an order of magnitude, the pressure and/or impulse values were greater or less than measurements for the same explosives. If the L/D ratio was equal to or less than 1:1, pressure and impulse values were less; and if the L/D ratio was greater than 1:1, pressure and impulse values were higher. This was most noticeable for the extruded rod and hopper tests. The dryer bed geometry with L/D ratios that were approximately equal to or less than 0.1:1, had lower than expected measured values at the close-in scaled distances equal to or less than 3.57m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$), and greater than expected at scaled distances equal to or greater than 7.14 m/Kg$^{1/3}$ (18.0 ft/lb$^{1/3}$). Overall, the L/D ratio had the most significant effect.

There were other factors affecting the measurement of the blast pressure and impulse. These factors include: energy of the explosive; density; explosive products; specific heat ratio; detonation velocity; physical parameters such as barometric pressure, humidity, air density, sonic velocity in air, and the specific heat ratio of the air. These factors were not controllable in many instances. The chemical properties of the explosives were dictated by the test requirements and the physical parameters were dictated by the test site. These effects were minimal in the influence of the measured parameters.

Whenever possible, all testing was standardized. The use of the witness plate minimized the difference in ground effect variables. The scaled distances were held constant throughout many of the experiments. There was an attempt to control as many of the chemical and physical parameters as possible.

The instrumentation utilized by the various experimenters varied and had a significant effect on the measured output. The limiting factor for each experimenter was the recording systems which varied from a low of 20 kHZ to a high of 500 kHZ. This difference in frequency response can represent significant difference in the measure value. Figure 96 shows the difference between peak pressure and impulse for a 20, 80 and a 500 kHz system.

Tables 48 and 49 represent the summary of the results for each of the explosives being tested. Table 48 is a summary of pressure and impulse and Table 49 is the TNT equivalency of each of the materials as they are represented by the geometry, physical characteristics, configuration and L/D ratio.

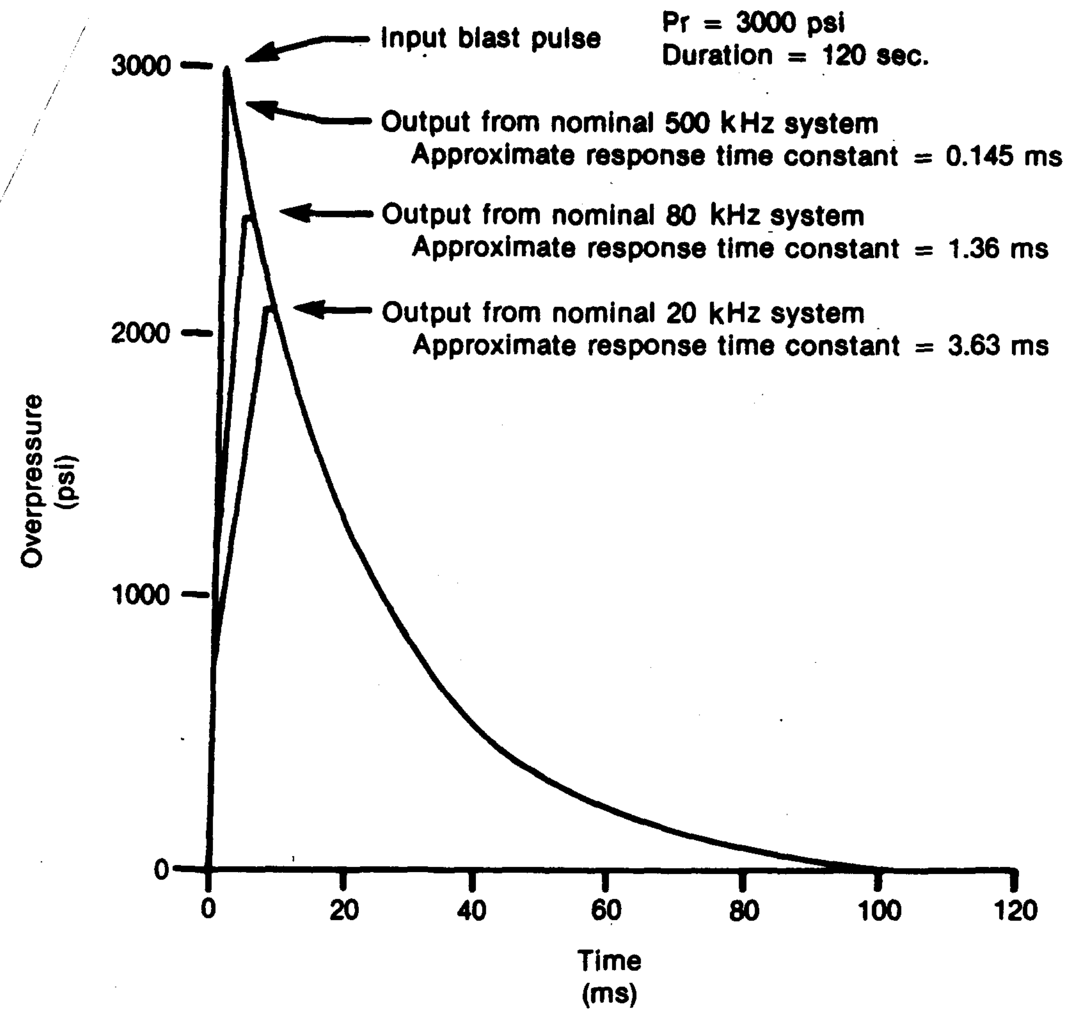


Figure 96/. Data processing system output versus the effects of system frequency response limitations on a typical blast pulse measurement.

Table 48. Summary of Peak Pressure and Scaled Positive Impulse for Bulk Explosive and High Exp

Test Materials	Geometry	Physical Characteristics	Configuration	L/D Ratio (x:1)	Peak Pressure (psi			
					Z = 3.0		Z = 40	
					P	I	P	I
Composition A3	Orthorhombic	Dry Powder	Shipping Containers	0.5:1	437.34	35.23	184.42	25.1
Composition A5	Orthorhombic	Dry Powder	Shipping Containers	0.4:1	239.71	40.43	147.70	29.5
	Cylindrical	Dry Powder	Shipping Containers	1.6:1	280.97	43.65	196.59	27.0
Composition B	Hemispherical	Cast	Bare Charge	1:1	102.89	16.04	58.90	14.0
	Spherical	Cast	Bare Charge	1:1	228.63	42.12	110.92	31.8
	Cylindrical	Cast	Bare Charge	1:1	230.11	33.65	111.03	25.5
Composition C4	Orthorhombic	Plastic	Shipping Container	0.5:1	366.24	36.17	172.00	22.7
	Orthorhombic	Plastic	Dryer Belt	0.1:1	145.18	12.57	67.50	9.8
Cyclotol 70/30	Orthorhombic	Chips	Shipping Containers	0.6:1	407.47	38.16	196.98	25.6
	Truncated Prism	Chips	Hoppers	2:1	538.95	37.72	369.90	33.7
EAK	Cylindrical	Chips	Shipping Containers	0.6:1	155.47	17.35	68.92	12.7
	Cylindrical	Chips	Shipping Containers	0.6:1	146.81	19.75	25.02	11.4
Guanidine Nitrate	Orthorhombic	Dry Powder	Storage Bins	1:1	136.46	19.93	66.72	14.0
HMX	Orthorhombic	Wet W/Alcohol	Transfer Box	0.5:1	323.90	17.27	193.46	19.2
	Cylindrical	Wet W/Alcohol	Shipping Containers	0.8:1	301.83	17.69	158.63	14.2
LX-14	Orthorhombic	Dry Powder	Shipping Containers	0.4:1	350.96	40.03	206.94	26.
	Orthorhombic	Powder and Cast	Transfer Cart	0.6:1	334.27	28.22	141.70	25.
	Cylindrical	Pressed Billets	Bare Charge	2:1	279.27	12.66	148.28	26.
Nitrocellulose	Orthorhombic	Wet W/Alcohol	Feeder Tub	1.2:1	161.77	17.07	82.92	13.
	Orthorhombic	Wet W/Alcohol	Dryer Bed	0.1:1	153.18	16.12	63.02	11.
	Cylindrical	Wet W/Alcohol	Storage/Shipping Container	1:1	187.14	20.65	78.31	13.
Nitroglycerine	Cylindrical	Liquid	Transfer Container	1:1	368.59	27.63	135.82	19.
Nitroquanidine	Orthorhombic	Dry Powder	Storage Bins	1:1	151.60	17.88	82.76	16.
Octol 75/25	Orthorhombic	Chips	Shipping Container	0.7:1	443.20	38.61	226.67	27.
	Truncated Prism	Chips	Hoppers	2:1	524.05	41.30	302.28	31.
PBXC-203	Cylindrical	Dry Powder	Powder Barrel	2:1	280.49	31.67	158.35	27.
	Cylindrical	Extruded Rod	Press Die	20:1	273.49	32.80	170.74	26.
PBXN-106	Orthorhombic	Dry Powder	Shipping Container	0.5:1	397.45	34.9[illegible]	233.6[illegible]	[illegible]
	Orthorhomobic	Dry Powder	Nutsche	0.5:1	427.10	37.49	276.29	29.
	Orthorhomobic	Dry Powder	Nutsche	0.5:1	427.72	37.72	245.78	27.
PBXW-109	Orthorhomobic	Dry Powder	Shipping Container	0.5:1	370.50	28.88	214.53	24.
	Orthorhomobic	Dry Powder	Nutsche	0.5:1	421.27	33.49	238.00	24.
	Orthorhomobic	Dry Powder	Nutsche	0.5:1	404.58	29.24	235.08	21.
RDX 98/2	Orthorhombic	Wet W/Alcohol	Nutsche Container	0.6:1	453.26	25.22	234.15	22.
	Cylindrical	Wet W/Alcohol	Shipping Container	1:1	332.01	22.22	189.73	18.
	Cylindrical	Slurry	Test Charge	1:1	148.76	26.53	84.40	21.
TNT	Orthorhombic	Flake	Shipping Container	0.8:1	414.64	35.02	212.66	33.
	Cylindrical	Flake	Shipping Drum	1.8:1	338.08	34.96	161.29	23.
	Truncated Prism	Flake	Hopper	2:1	404.31	37.30	229.36	35.
	Hemispherical	Cast	Calibration	1:1	150.59	16.62	86.53	14.
Lead Azide	Cylindrical	Wet/Dry	Bag/Beakers	1:1	34.54	8.55	20.10	6.
Lead Styphnate	Cylindrical	Wet/Dry	Standard Shipping Drums	1:1	62.50	10.02	31.26	7.
	Cylindrical	Wet/Dry	Bag/Beaker	1:1	106.75	15.46	56.03	12.
Tetracene	Cylindrical	Wet/Dry	Bag/Brakers	1:1	24.9	7.35	15.95	6.
M42 Grenades	Cylindrical	Cast	Tray of 64	0.03:1	91.28	11.35	36.14	9.
M483 Projectile	Cylindrical	88 Sub Munitions	155mm Munition	4:1	121.67	20.98	70.47	16.
M718/741 Projectile	Cylindrical	9 TAAM Mines	155mm Munition	4:1	132.52	23.85	68.46	13.

le 48. Summary of Peak Pressure and Scaled Positive Impulse for Bulk Explosive and High Explosive End-Item Munitions

eometry	Physical Characteristics	Configuration	L/D Ratio (x:1)	Peak Pressure (psi) & Scaled Positive Impulse (psi - msec/$w^{1/3}$)											
				Z = 3.0		Z = 40		Z = 5.4		Z = 9.0		Z = 18.0		Z = 40.0	
				P	I	P	I	P	I	P	I	P	I	P	I
orhombic	Dry Powder	Shipping Containers	0.5:1	437.34	35.23	184.42	25.10	71.79	14.41	16.30	6.56	3.85	5.40	1.45	2.35
orhombic	Dry Powder	Shipping Containers	0.4:1	239.71	40.43	147.70	29.54	59.21	19.67	11.46	9.52	3.38	4.35	1.64	2.67
ndrical	Dry Powder	Shipping Containers	1.6:1	280.97	43.65	196.59	27.00	81.49	16.73	15.12	8.47	4.07	4.55	1.40	2.27
spherical	Cast	Bare Charge	1:1	102.89	16.04	58.90	14.00	32.29	11.66	11.62	7.91	3.30	4.55	1.40	2.27
rical	Cast	Bare Charge	1:1	228.63	42.12	110.92	31.81	51.33	22.04	14.97	11.60	3.85	5.60	1.10	2.17
ndrical	Cast	Bare Charge	1:1	230.11	33.65	111.03	25.51	52.96	17.36	15.28	8.81	3.57	4.32	0.94	1.93
orhombic	Plastic	Shipping Container	0.5:1	366.24	36.17	172.00	22.79	74.51	14.70	17.90	7.71	3.49	3.93	1.46	2.43
orhombic	Plastic	Dryer Belt	0.1:1	145.18	12.57	67.50	9.80	26.77	8.96	9.98	8.43	5.56	5.09	1.78	2.51
orhombic	Chips	Shipping Containers	0.6:1	407.47	38.16	196.98	25.63	78.41	16.84	16.66	8.60	3.83	4.04	1.52	1.97
cated Prism	Chips	Hoppers	2:1	538.95	37.72	369.90	33.71	137.74	23.56	20.35	9.52	4.49	2.90	1.18	2.07
ndrical	Chips	Shipping Containers	0.6:1	155.47	17.35	68.92	12.70	32.15	9.55	12.85	5.40	4.02	3.65	1.13	1.63
ndrical	Chips	Shipping Containers	0.6:1	146.81	19.75	25.02	11.47	35.58	9.95	15.33	6.39	4.02	3.18	1.28	1.79
orhombic	Dry Powder	Storage Bins	1:1	136.46	19.93	66.72	14.08	32.43	10.12	10.08	5.77	2.32	2.69	0.51	1.12
orhombic	Wet W/Alcohol	Transfer Box	0.5:1	323.90	17.27	193.46	19.23	81.51	13.54	15.47	5.95	2.83	2.24	1.07	0.78
ndrical	Wet W/Alcohol	Shipping Containers	0.8:1	301.83	17.69	158.63	14.21	66.42	10.52	13.15	6.25	3.75	3.27	1.24	1.18
orhombic	Dry Powder	Shipping Containers	0.4:1	350.96	40.03	206.94	26.55	80.43	15.88	14.71	7.36	3.60	4.31	1.00	2.16
orhombic	Powder and Cast	Transfer Cart	0.6:1	334.27	28.22	141.70	25.07	57.49	17.67	23.80	8.42	6.37	3.11	1.75	1.41
ndrical	Pressed Billets	Bare Charge	2:1	279.27	12.66	148.28	26.13	70.88	26.98	20.65	12.66	5.28	3.89	1.34	1.27
orhombic	Wet W/Alcohol	Feeder Tub	1.2:1	161.77	17.07	82.92	13.39	38.80	10.39	11.82	6.75	3.76	3.76	1.11	1.92
orhombic	Wet W/Alcohol	Dryer Bed	0.1:1	153.18	16.12	63.02	11.17	27.65	8.44	8.77	6.09	2.92	4.10	1.15	1.71
ndrical	Wet W/Alcohol	Storage/Shipping Container	1:1	187.14	20.65	78.31	13.84	36.98	10.14	12.55	6.58	3.38	3.52	1.08	1.60
ndrical	Liquid	Transfer Container	1:1	368.59	27.63	135.82	19.21	52.61	13.82	13.13	8.49	3.12	4.61	1.03	2.14
orhombic	Dry Powder	Storage Bins	1:1	151.60	17.88	82.76	16.97	42.06	13.34	12.83	6.73	2.91	2.40	0.92	1.48
orhombic	Chips	Shipping Container	0.7:1	443.20	38.61	226.67	27.00	82.70	18.89	15.48	10.66	4.47	5.27	1.66	2.60
cated Prism	Chips	Hoppers	2:1	524.05	41.30	302.28	31.79	114.80	23.13	19.81	12.21	4.36	4.32	1.20	1.07
ndrical	Dry Powder	Powder Barrel	2:1	280.49	31.67	158.35	27.25	74.62	18.73	20.09	9.39	5.34	5.30	2.23	1.64
ndrical	Extruded Rod	Press Die	20:1	273.49	32.80	170.74	26.45	88.92	22.51	26.76	15.19	6.87	5.88	2.14	2.54
orhomobic	Dry Powder	Shipping Container	0.5:1	397.45	34.9[illegible]	233.6[illegible]	[illegible]	[illegible]	16.63	14.54	[illegible]	3.49	3.65	1.34	1.34
orhomobic	Dry Powder	Nutsche	0.5:1	427.10	37.49	276.29	29.61	161.[illegible]	21.64	15.[illegible]	11.51	[illegible]	[illegible]	1.14	[illegible]
orhomobic	Dry Powder	Nutsche	0.5:1	427.72	37.72	245.78	27.16	98.21	19.2[illegible]	18.23	10.77	3.83	4.88	1.29	1.96
orhomobic	Dry Powder	Shipping Container	0.5:1	370.50	28.88	214.53	24.24	80.10	18.10	13.33	8.63	3.09	3.99	1.33	2.09
orhomobic	Dry Powder	Nutsche	0.5:1	421.27	33.49	238.00	24.68	89.60	17.95	15.08	10.44	3.20	5.01	1.22	2.15
orhomobic	Dry Powder	Nutsche	0.5:1	404.58	29.24	235.08	21.47	85.17	15.55	13.95	8.99	3.59	4.27	1.23	1.81
orhombic	Wet W/Alcohol	Nutsche Container	0.6:1	453.26	25.22	234.15	22.12	89.83	18.41	16.74	11.19	3.72	4.33	1.74	0.96
ndrical	Wet W/Alcohol	Shipping Container	1:1	332.01	22.22	189.73	18.03	79.12	14.07	17.03	8.59	4.52	3.82	1.60	1.23
ndrical	Slurry	Cast Charge	1:1	148.76	26.53	84.40	21.31	46.73	16.62	17.08	10.39	4.36	5.01	0.90	1.89
orhombic	Flake	Shipping Container	0.8:1	414.64	35.02	212.66	33.85	78.26	17.78	14.29	5.31	3.48	3.83	0.97	1.93
ndrical	Flake	Shipping Drum	1.8:1	338.08	34.96	161.29	23.22	65.72	13.74	16.15	6.40	4.86	4.01	1.38	1.79
cated Prism	Flake	Hopper	2:1	404.31	37.30	229.36	35.82	91.49	19.97	17.33	5.48	3.72	4.12	1.04	1.78
spherical	Cast	Calibration	1:1	150.59	16.62	86.53	14.58	48.54	12.14	18.15	8.67	4.77	4.66	1.03	1.87
ndrical	Wet/Dry	Bag/Beakers	1:1	34.54	8.55	20.10	6.77	11.58	5.23	4.67	3.39	1.52	1.72	0.56	0.33
ndrical	Wet/Dry	Standard Shipping Drums	1:1	62.50	10.02	31.26	7.83	16.86	6.17	6.28	3.95	1.71	1.90	0.64	0.92
ndrical	Wet/Dry	Bag/Beaker	1:1	106.75	15.46	56.03	12.67	26.64	9.88	8.06	6.06	2.44	2.95	0.83	1.38
ndrical	Wet/Dry	Bag/Brakers	1:1	24.9	7.35	15.95	6.05	9.87	5.00	4.44	3.41	1.70	1.69	0.67	0.73
ndrical	Cast	Tray of 64	0.03:1	91.28	11.35	36.14	9.63	20.02	8.74	10.83	7.18	4.57	3.97	1.27	1.61
ndrical	88 Sub Munitions	155mm Munition	4:1	121.67	20.98	70.47	16.89	40.84	12.83	16.21	7.41	4.62	3.22	1.46	1.24
ndrical	9 TAAM Mines	155mm Munition	4:1	132.52	23.85	68.46	13.80	34.38	7.80	10.64	2.42	2.17	0.79	0.35	0.17

Table [illegible]. Summary of Peak Pressure and Scaled Positive Impulse TNT Equivalency Values for Bulk

Test Materials	Geometry	Physical Characteristics	Configuration	L/D Ratio (x:1)	Peak Pres Z = 3.0 P	I
Composition A3	Orthorhombic	Dry Powder	Shipping Containers	0.5:1	5.3	2.9
Composition A5	Orthorhombic	Dry Powder	Shipping Containers	0.4:1	2.3	3.4
	Cylindrical	Dry Powder	Shipping Containers	1.6:1	2.8	3.4
Composition B	Hemispherical	Cast	Bare Charge	1:1	1.0	1.1
	Spherical	Cast	Bare Charge	1:1	2.1	3.8
	Cylindrical	Cast	Bare Charge	1:1	2.1	2.6
Composition C4	Orthorhombic	Plastic	Shipping Container	0.5:1	3.1	1.0
	Orthorhombic	Plastic	Dryer Belt	0.1:1	1.2	0.5
Cyclotol 70/30	Orthorhombic	Chips	Shipping Containers	0.6:1	4.6	3.2
	Truncated Prism	Chips	Hoppers	2:1	6.7	3.4
EAK	Cylindrical	Chips	Shipping Containers	0.59:1	1.1	0.8
	Cylindrical	Chips	Shipping Containers	0.59:1	1.0	1.0
Guanidine Nitrate	Orthorhombic	Dry Powder	Storage Bins	1:1	1.0	1.0
HMX	Orthorhombic	Wet W/Alcohol	Transfer Box	0.5:1	3.4	0.9
	Cylindrical	Wet W/Alcohol	Shipping Containers	0.8:1	3.0	0.9
LX-14	Orthorhombic	Dry Powder	Shipping Containers	0.4:1	3.9	3.5
	Orthorhombic	Powder and Cast	Transfer Cart	0.6:1	3.5	1.9
	Cylindrical	Pressed Billets	Bare Charge	2:1	3.0	0.7
Nitrocellulose	Orthorhombic	Wet W/Alcohol	Feeder Tub	1.2:1	1.3	0.8
	Orthorhombic	Wet W/Alcohol	Dryer Bed	0.1:1	1.3	0.8
	Cylindrical	Wet W/Alcohol	Storage/Shipping Container	1:1	1.6	1.1
Nitroglycerine	Cylindrical	Liquid	Transfer Container	1:1	4.0	1.9
Nitroguanidine	Orthorhombic	Dry Powder	Storage Bins	1:1	1.1	1.1
Octol 75/25	Orthorhombic	Chips	Shipping Container	0.7:1	5.2	2.9
	Truncated Prism	Chips	Hoppers	2:1	6.5	2.9
PBXC-203	Cylindrical	Dry Powder	Powder Barrel	2:1	2.8	2.3
	Cylindrical	Extruded Rod	Press Die	20:1	2.7	2.5
PBXN-106	Orthorhombic	Dry Powder	Shipping Container	0.5:1	4.5	2.5
	Orthorhombic	Dry Powder	Nutsche	0.5:1	[illegible]	[illegible]
	Orthorhombic	Dry Powder	Nutsche	0.5:1	4.9	2.6
PBXW-109	Orthorhombic	Dry Powder	Shipping Container	0.5:1	4.1	2.0
	Orthorhombic	Dry Powder	Nutsche	0.5:1	4.8	2.3
	Orthorhombic	Dry Powder	Nutsche	0.5:1	4.5	2.0
RDX 98/2	Orthorhombic	Wet W/Alcohol	Nutsche Container	0.6:1	5.3	1.2
	Cylindrical	Wet W/Alcohol	Shipping Container	1:1	3.5	1.3
	Cylindrical	Slurry	Test Charge	1:1	1.2	1.7
TNT	Orthorhombic	Flake	Shipping Container	0.8:1	4.7	2.7
	Cylindrical	Flake	Shipping Drum	1.8:1	3.6	2.7
	Truncated Prism	Flake	Hopper	2:1	4.5	3.0
	Hemispherical	Cast	Calibration	1:1	1.0	0.9
Lead Azide	Cylindrical	Wet/Dry	Bag/Beakers	1:1	0.2	6.3
Lead Styphnate	Cylindrical	Wet/Dry	Standard Shipping Drums	1:1	0.3	0.4
	Cylindrical	Wet/Dry	Bag/Beaker	1:1	0.4	0.4
Tetracene	Cylindrical	Wet/Dry	Bag/Brakers	1:1	0.1	0.2
M42 Grenades	Cylindrical	Cast	Tray of 64	0.03:1	0.6	0.5
M483 Projectile	Cylindrical	88 Sub Munitions	155mm Munition	4:1	0.7	1.1
M718/741 Projectile	Cylindrical	9 TAAM Mines	155mm Munition	4:1	1.0	1.4

sitive Impulse TNT Equivalency Values for Bulk Explosive and High Explosive End-Item Munitions

		Peak Pressure (psi) & Scaled Positive Impulse (psi - msec/$w^{1/3}$)											
	L/D Ratio	Z = 3.0		Z = 4.0		Z = 5.4		Z = 9.0		Z = 18.0		Z = 40.0	
Configuration	(x:1)	P	I	P	I	P	I	P	I	P	I	P	I
Shipping Containers	0.5:1	5.3	2.9	3.5	2.0	2.5	1.7	1.5	0.7	1.3	1.5	1.6	1.3
Shipping Containers	0.4:1	2.3	3.4	2.8	3.0	2.0	2.3	1.0	1.4	1.0	1.1	2.1	1.6
Shipping Containers	1.6:1	2.8	3.4	4.2	5.5	3.0	1.5	1.5	1.3	1.4	1.0	1.5	1.3
Bare Charge	1:1	1.0	1.1	0.9	1.0	1.0	1.0	0.9	1.0	0.8	0.9	0.7	0.8
Bare Charge	1:1	2.1	3.8	1.9	3.6	1.6	2.9	1.4	2.0	1.2	1.6	0.9	1.2
Bare Charge	1:1	2.1	2.6	1.9	2.4	1.7	1.9	1.5	1.2	1.1	1.1	0.6	1.0
Shipping Container	0.5:1	3.1	1.0	3.3	1.2	3.2	1.6	1.6	0.7	0.9	0.9	1.4	2.1
Dryer Belt	0.1:1	1.2	0.5	0.9	0.5	0.7	0.5	0.6	1.2	2.4	1.4	2.6	1.5
Shipping Containers	0.6:1	4.6	3.2	4.1	2.4	3.0	1.9	1.6	1.2	1.2	1.0	1.7	1.0
Hoppers	2:1	6.7	3.4	10.0	3.5	6.0	3.5	2.2	1.2	1.6	0.6	1.0	1.1
Shipping Containers	0.59:1	1.1	0.8	0.8	0.7	0.7	0.6	1.0	0.5	1.2	0.8	0.7	0.7
Shipping Containers	0.59:1	1.0	1.0	0.9	0.6	0.8	0.7	1.3	0.7	1.2	0.7	1.0	0.8
Storage Bins	1:1	1.0	1.0	1.0	0.9	1.0	0.8	0.8	0.6	0.5	0.4	0.2	0.4
Transfer Box	0.5:1	3.4	0.9	4.0	1.0	3.1	1.8	1.5	0.6	0.6	0.4	0.8	0.2
Shipping Containers	0.8:1	3.0	0.9	3.5	0.9	1.7	0.8	1.2	0.7	1.1	0.7	1.1	0.5
Shipping Containers	0.4:1	3.9	3.5	3.6	2.4	3.2	1.8	1.3	0.9	1.1	1.1	0.7	1.2
Transfer Cart	0.6:1	3.5	1.9	2.6	2.4	1.9	2.0	2.6	1.2	2.9	0.7	2.4	0.6
Bare Charge	2:1	3.0	0.7	2.7	2.1	2.8	3.9	2.2	1.4	2.1	0.9	1.3	0.5
Feeder Tub	1.2:1	1.3	0.8	1.2	0.8	1.2	0.5	1.0	1.0	1.2	0.9	0.9	0.8
Dryer Bed	0.1:1	1.3	0.8	0.8	0.6	0.6	0.6	0.6	0.7	0.7	1.0	0.9	0.8
Storage/Shipping Container	1:1	1.6	1.1	1.2	0.9	1.0	0.8	1.1	0.8	1.0	0.8	0.8	0.8
Transfer Container	1:1	4.0	1.9	2.5	1.4	1.7	1.3	1.2	1.1	0.8	1.2	0.7	1.2
Storage Bins	1:1	1.1	1.1	1.3	1.3	1.3	1.0	0.9	0.9	0.8	0.4	0.6	0.7
Shipping Container	0.7:1	5.2	2.9	5.3	2.8	2.9	2.7	1.5	1.3	1.6	1.6	2.2	1.6
Hoppers	2:1	6.5	2.9	7.0	3.3	5.3	4.3	2.0	1.5	1.5	1.2	1.0	0.2
Powder Barrel	2:1	2.8	2.3	3.1	2.7	2.7	2.1	2.1	1.4	2.2	1.5	4.5	0.8
Press Die	20:1	2.7	2.5	3.4	2.5	3.4	3.0	3.1	3.0	3.3	1.8	3.9	1.5
Shipping Container	0.5:1	4.5	2.5	4.7	2.2	3.3	1.7	1.3	1.4	1.0	0.7	1.3	1.0
Nutsche	0.5:1	[illegible]	[illegible]	[illegible]	3.1	4.0	2.7	[illegible]	[illegible]	0.9	1.2	0.9	1.2
Nutsche	0.5:1	4.9	2.6	5.4	3.6	4.1	1.8	1.8	1.1	1.2	0.9	1.2	0.7
Shipping Container	0.5:1	4.1	2.0	3.7	2.3	2.9	1.9	1.2	1.2	0.8	0.9	1.2	1.1
Nutsche	0.5:1	4.8	2.3	5.1	2.8	4.1	1.8	1.4	1.8	0.8	1.3	1.1	1.1
Nutsche	0.5:1	4.5	2.0	4.9	1.9	3.2	1.7	1.2	1.0	1.0	0.8	1.1	1.1
Nutsche Container	0.6:1	5.3	1.2	5.3	2.4	3.4	2.3	1.7	0.9	1.2	1.2	2.5	0.3
Shipping Container	1:1	3.5	1.3	3.9	1.5	2.3	1.1	1.7	1.3	1.6	0.9	2.0	0.5
Test Charge	1:1	1.2	1.7	1.3	1.8	1.4	1.8	1.7	1.6	1.5	1.3	0.5	1.0
Shipping Container	0.8:1	4.7	2.7	4.5	3.8	2.9	2.0	1.3	0.6	1.0	0.9	0.6	1.0
Shipping Drum	1.8:1	3.6	2.7	3.1	2.1	2.3	1.3	1.6	0.7	1.8	1.0	1.4	0.9
Hopper	2:1	4.5	3.0	5.0	4.2	3.6	2.4	1.7	0.8	1.2	1.0	0.7	0.9
Calibration	1:1	1.0	0.9	1.3	0.9	1.6	1.1	1.5	1.2	1.6	1.3	0.7	0.9
Bag/Beakers	1:1	0.2	6.3	0.2	0.3	0.2	6.3	0.2	0.3	0.2	0.3	0.2	0.1
Standard Shipping Drums	1:1	0.3	0.4	0.4	0.4	0.3	0.4	0.3	0.5	0.3	0.4	0.1	0.1
Bag/Beaker	1:1	0.4	0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.2	0.3	0.3	0.3
Bag/Brakers	1:1	0.1	0.2	0.1	0.2	0.2	0.2	0.2	0.3	0.2	0.3	0.3	0.2
Tray of 64	0.03:1	0.6	0.5	0.4	0.5	0.5	0.7	0.1	0.8	1.7	1.0	1.2	0.8
155mm Munition	4:1	0.7	1.1	1.1	1.2	1.1	1.1	1.6	1.0	1.7	0.7	1.6	0.5
155mm Munition	4:1	1.0	1.4	1.0	0.9	1.0	0.5	0.9	0.2	0.4	0.1	0.1	0.1

BLACK POWDER[24]

OBJECTIVE

The primary objective of this program was to determine the maximum airblast output in terms of TNT equivalency of black powder in weight ranges of 227 to 2041 kg (400 to 4500 lb).

MATERIAL

Black powder Class I, 4 by 8; Class 6, 20 by MIL-P-223B Grade A1, 4 by 8, Grade A-3, 12 by 16; Grade A-3a, 12 by 20 MIL-P-223A were tested in loose powder form.

TEST SETUP

The black powder was evaluated in containers with a size and shape that represented full-scale simulation of glaze barrels, tote bins and storage bins. Boxes for the storage bins and tote bins were constructed from plywood so that they would afford minimum confinement. The black powder was loosely poured into the boxes and then tested at the apparent bulk density. There was no attempt to compress the material. In tests that used bagged powder, additional loose black powder was poured into the container to eliminate the voids.

The glaze barrel test configuration simulated the worst case condition where the barrel was in the shutdown mode and all of the powder had collected at the bottom of the barrel.

INSTRUMENTATION

Nine pressure gages were flush mounted in a 0.5 m (1.67 ft) square by 25.4 mm (1 inch) thick steel plates which were, in turn, flush mounted to the ground with stakes. They were located at discrete intervals on a radial line from ground zero. The gage positions ranged from 4.88 to 182.88 m (16 to 600 ft) from ground zero. Only six pressure transducers were used during any one test.

RESULTS

The peak pressure and scaled positive impulse values of all tests were combined and are reported in Table 50 and Figure 97. Results of the individual tests can be found in the orginal test report.

DISCUSSION

Peak pressure for the combined values of all the black powder tests in all test configurations were less than expected at all scaled distances of the experiment. Peak pressure values were 389, 227, 128, 49, 14, and 3.8 kPa (56.5, 33.1, 18.6, 7.10, 2.09, and 0.56 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 0.3, 0.4, 0.4, 0.4, 0.3, and 0.2 times equal amounts of TNT at the same scaled distances respectively. Scaled positive impulse values were less than expected at all scaled distances of the experiment. The combined scaled positive impulse values were 111, 89, 69, 44, 22, and 8.8 kPa-ms/kg$^{1/3}$ (12.4, 9.9, 7.7, 4.9, 2.4, and 0.98 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0 and 40.0 ft/lb$^{1/3}$), respectively. These combined scaled positive impulse values equate to 0.5, 0.5, 0.5, 0.5, 0.4, and 0.4 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) The airblast parameters and TNT equivalency results for weight ranging from 227 to 2041 kg (500 to 4500 lb) did not show significant differences due to charge weight, container shape or booster weight.

(2) The differences in container confinement had a negligible effect on airblast output and TNT equivalency.

(3) The black powder scaled as a function of the cube root of the charge weight.

Table 50[. Summary of Results of Hemispherical Surface Burst, Peak Pressure, and Scaled Positive Impulse for Black Powder with L/D=1:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	56.53	389.78	12.41	111.35	22.000	8.727	1.50	10.32	1.95	17.47
4.000	1.587	33.04	227.80	9.88	88.64	23.000	9.124	1.39	9.59	1.85	16.63
5.000	1.983	21.55	148.61	8.21	73.69	24.000	9.521	1.30	8.94	1.77	15.86
6.000	2.380	15.19	104.75	7.02	63.01	25.000	9.917	1.21	8.36	1.69	15.15
7.000	2.777	11.33	78.10	6.12	54.96	26.000	10.314	1.14	7.84	1.62	14.50
8.000	3.174	8.81	60.75	5.42	48.67	27.000	10.711	1.07	7.37	1.55	13.89
9.000	3.570	7.08	48.81	4.86	43.60	28.000	11.108	1.01	6.94	1.49	13.33
10.000	3.967	5.84	40.25	4.39	39.44	29.000	11.504	0.95	6.55	1.43	12.81
11.000	4.364	4.91	33.88	4.01	35.96	30.000	11.901	0.90	6.20	1.37	12.32
12.000	4.760	4.21	29.00	3.68	33.00	31.000	12.298	0.85	5.87	1.32	11.86
13.000	5.157	3.65	25.19	3.39	30.45	32.000	12.694	0.81	5.63	1.28	11.52
14.000	5.554	3.21	22.13	3.15	28.24	33.000	13.091	0.77	5.30	1.23	11.03
15.000	5.950	2.85	19.65	2.93	26.31	34.000	13.488	0.73	5.04	1.19	10.65
16.000	6.347	2.55	17.59	2.74	24.60	35.000	13.884	0.70	4.80	1.15	10.30
17.000	6.744	2.30	15.87	2.57	23.08	36.000	14.281	0.66	4.58	1.11	9.96
18.000	7.141	2.09	14.41	2.42	21.72	37.000	14.678	0.63	4.38	1.07	9.65
19.000	7.537	1.91	13.16	2.28	20.50	38.000	15.075	0.61	4.19	1.04	9.35
20.000	7.934	1.75	12.08	2.16	19.39	39.000	15.471	0.58	4.01	1.01	9.06
21.000	8.331	1.62	11.14	2.05	18.39	40.000	15.868	0.56	3.84	0.98	8.79

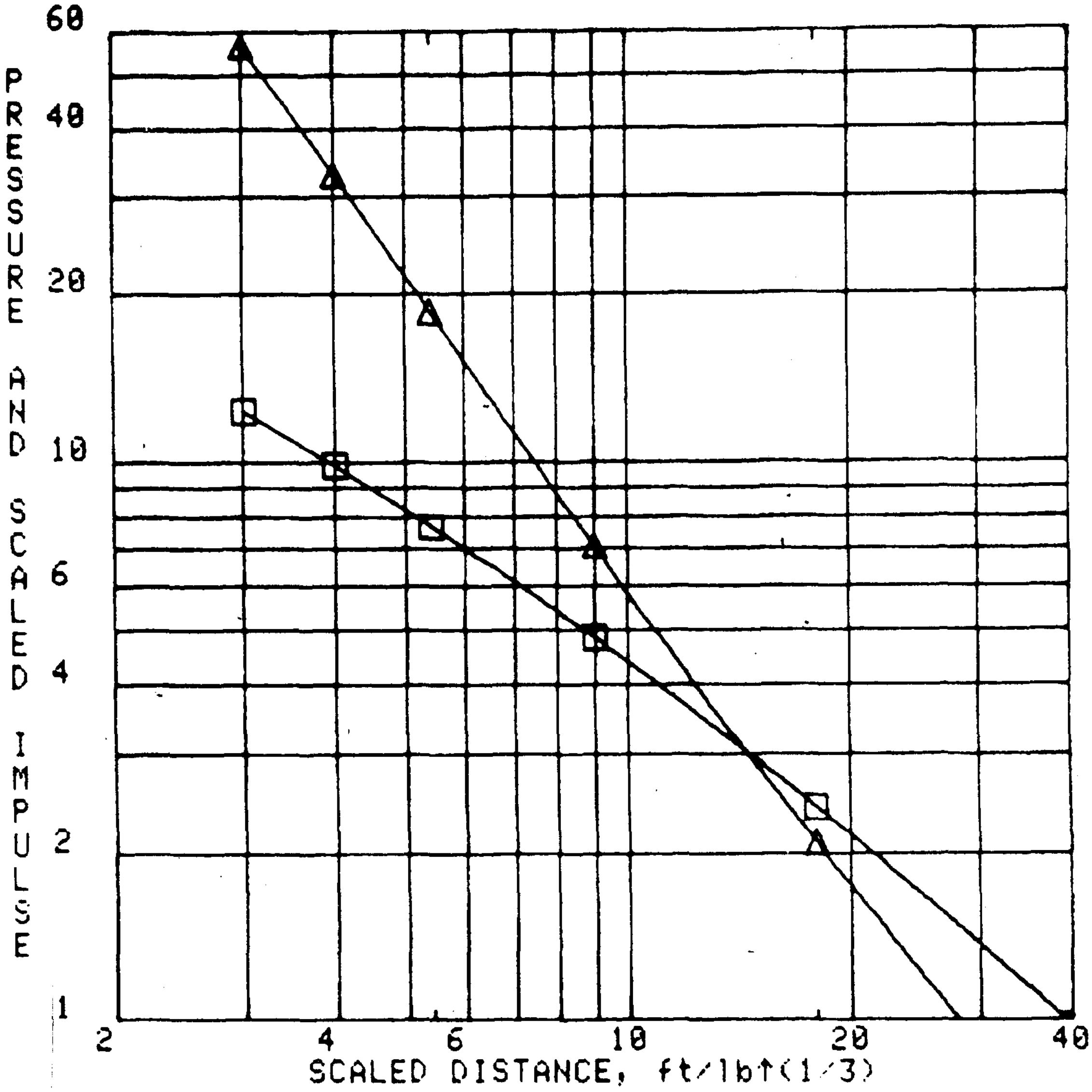


Figure 97. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for Black Powder with L/D =1:1.

OBJECTIVE

The objective of this test program was to determine the maximum airblast output from the detonation of Benite propellant in terms of peak pressure and positive impulse compared to known characteristics of hemispherical surface bursts of TNT.

MATERIAL

Benite propellant conforming to Military Specification MIL-B-45451B, was used throughout the testing. Specifically, the test material consisted of extruded Benite strands 2.03 mm (0.08 inch) in diameter by 254 mm (10 inches) long. The Benite propellant was composed of 40% nitrocellulose. 44.3% potassium nitrate, 6.3% sulfur, 9.4% charcoal, and 0.5% ethyl centralite (added).

TEST SETUP

Airblast output was measured in an orthorhombic container made of wood and fiberboard filled with 10.43 kg (22.99 lb) and in a simulated packout orthorhombic container filled with 41.8 kg (92.15 lb) of propellant.

A conical-shaped booster charge of Compositon C4 explosives was buried in the center of each container with the apex protruding above or flush with the top surface of the test charge. A J2 engineers' special blasting cap was used as the initiating source. The booster weight varied from 2% to 17% of the charge weight.

INSTRUMENTATION

Twelve piezoelectric pressure transducers were mounted in steel witness plates flush with the ground surface in a 90 degree array. Scaled distances were 1.19, 2.72, 3.57, 4.37, 7.15 and 15.87 m/kg$^{1/3}$ (3.00, 6.86, 9.00, 11.02, 18.00, and 40.00 ft/lb$^{1/3}$).

RESULTS

The results of the 10.43-kg tests are given in Table 51 and Figure 98. The results of the 41.8-kg tests are given in Table 52 and Figure 99.

DISCUSSION

The pressure values for the 10.43-kg (23-lb) Benite propellant were less than expected at all scaled distances of the experiment. Peak pressure values were 288, 181, 98, 44, 14, and 3.9 kPa (41.70, 23.90, 14.20, 6.30, 2.10, and 0.56 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14 and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 8.0 and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 0.2, 0.1, 0.3, 0.2, 0.2, and 0.1 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were less than expected at all scaled distances of the experiment. Scaled positive impulse values were 137, 95, 68, 41, 21, and 6.6 kPa-ms/kg$^{1/3}$ (15.30, 10.50, 7.60, 4.70, 2.40, and 0.73 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.9, 0.7, 0.4, 0.4, 0.4, and 0.2 times equal amounts of TNT at the same scaled distances, respectively.

Peak pressure values for the 41.8-kg (92-lb) tests were less than expected at all scaled distances of the experiment. Peak pressure values were 421, 250, 145, 58, 16, and 5.5 kPa (61.1, 36.3, 21.1, 8.3, 2.4, and 0.8 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 0.3, 0.4, 0.5, 0.5, 0.1, and 0.3 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were less than expected at all scaled distances of the experiment. The scaled positive impulse values were 128, 84, 55, 32, 21, and 6.6 kPa-ms/kg$^{1/3}$ (14.30, 9.34, 6.16, 3.59, 2.29, and 0.73 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.7, 0.6, 0.3, 0.3, 0.4, and 0.2 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) The pressure and scaled impulse for the two different tests varied with each different charge weight.

(2) The pressure and scaled positive impulse values were less than expected at all scaled distances of the experiment.

(3) The orientation of the Benite strands within the shipping container (i.e., horizontal or vertical had no descernible effect on the resulting blast output).

Table 51. Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for Benite Propellant in Orthorhombic Containers, L/D=1:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	41.72	287.65	15.29	137.25	22.000	8.727	1.48	10.22	1.96	17.56
4.000	1.587	23.85	164.45	10.54	94.62	23.000	9.124	1.38	9.49	1.87	16.79
5.000	1.983	16.18	111.59	8.20	73.56	24.000	9.521	1.28	8.85	1.79	16.07
6.000	2.380	12.00	82.75	6.78	60.88	25.000	9.917	1.20	8.27	1.72	15.41
7.000	2.777	9.39	64.71	5.83	52.30	26.000	10.314	1.12	7.75	1.65	14.79
8.000	3.174	7.60	52.43	5.13	46.04	27.000	10.711	1.06	7.28	1.58	14.22
9.000	3.570	6.32	43.56	4.59	41.23	28.000	11.108	1.00	6.86	1.52	13.68
10.000	3.967	5.35	36.89	4.16	37.37	29.000	11.504	0.94	6.48	1.47	13.18
11.000	4.364	4.66	31.71	3.81	34.21	30.000	11.901	0.89	6.13	1.42	12.71
12.000	4.760	4.00	27.60	3.52	31.55	31.000	12.298	0.84	5.82	1.37	12.28
13.000	5.157	3.52	24.26	3.26	29.27	32.000	12.694	0.80	5.53	1.32	11.86
14.000	5.554	3.12	21.52	3.04	27.30	33.000	13.091	0.76	5.27	1.28	11.47
15.000	5.950	2.79	19.23	2.85	25.57	34.000	13.488	0.73	5.02	1.24	11.11
16.000	6.347	2.51	17.31	2.68	24.04	35.000	13.884	0.70	4.80	1.20	10.76
17.000	6.744	2.27	15.66	2.53	22.67	36.000	14.281	0.65	4.48	1.14	10.24
18.000	7.141	2.07	14.25	2.39	21.44	37.000	14.678	0.64	4.40	1.13	10.12
19.000	7.537	1.89	13.03	2.27	20.33	38.000	15.075	0.61	4.23	1.10	9.83
20.000	7.934	1.74	11.97	2.15	19.33	39.000	15.471	0.59	4.07	1.06	9.55
21.000	8.331	1.60	11.04	2.05	18.40	40.000	15.868	0.57	3.91	1.03	9.29

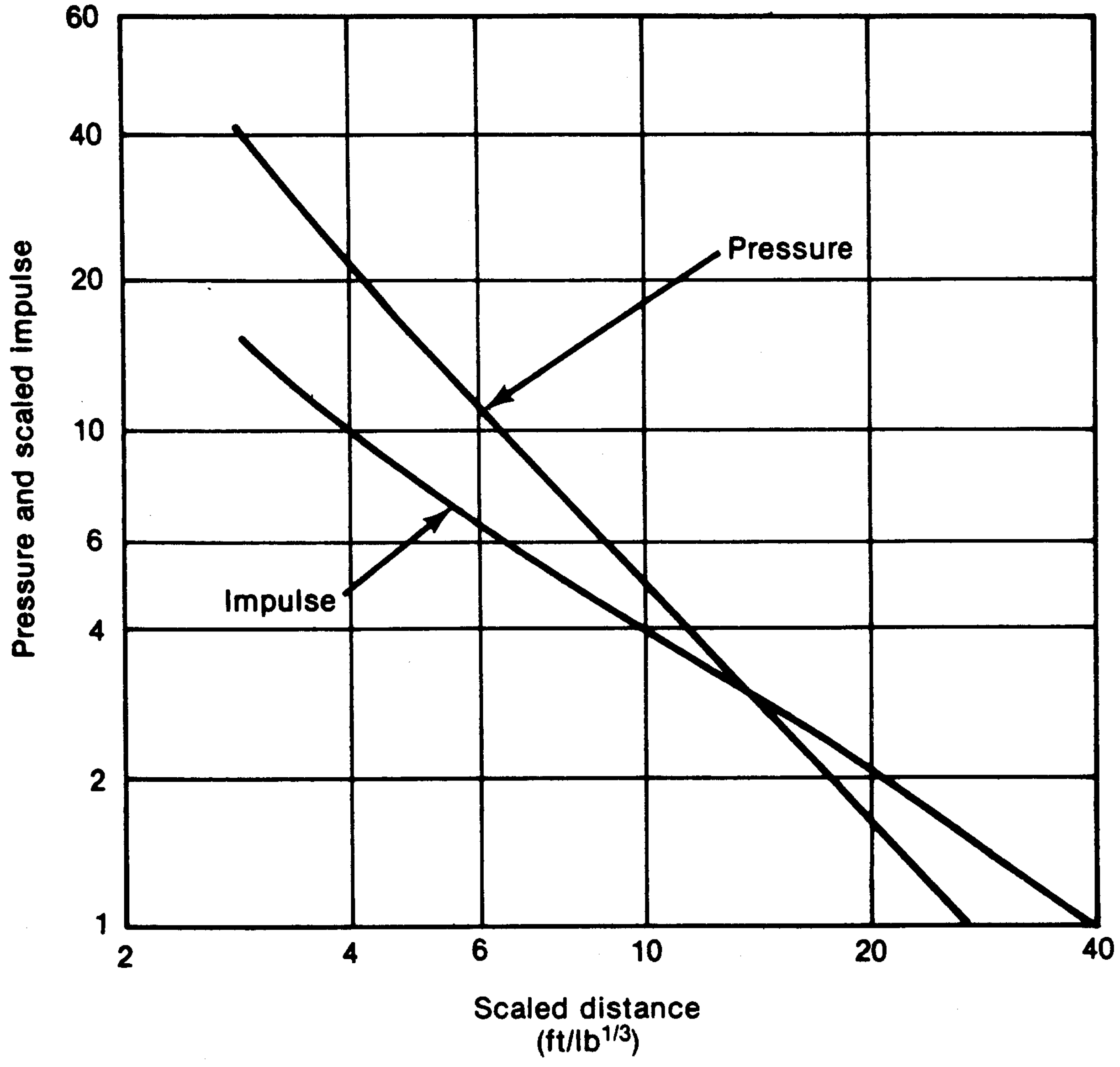


Figure 98. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for Benite Propellant in Orthorhombic Containers, L/D=1:1.

Table 52. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for Benite Propellant in Orthorhombic Containers, L/D=1:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	61.10	421.25	14.26	127.92	22.000	8.727	1.65	11.39	1.96	17.60
4.000	1.587	36.27	250.10	9.34	83.86	23.000	9.124	1.52	10.50	1.88	16.89
5.000	1.983	24.21	166.91	6.82	61.18	24.000	9.521	1.41	9.72	1.80	16.19
6.000	2.380	17.40	119.95	5.40	48.48	25.000	9.917	1.31	9.03	1.73	15.49
7.000	2.777	13.16	90.71	4.54	40.74	26.000	10.314	1.22	8.41	1.65	14.79
8.000	3.174	10.33	71.21	3.98	35.70	27.000	10.711	1.14	7.86	1.57	14.11
9.000	3.570	8.34	57.52	3.59	32.21	28.000	11.108	1.07	7.35	1.50	13.43
10.000	3.967	6.89	47.53	3.31	29.68	29.000	11.504	1.00	6.90	1.42	12.76
11.000	4.364	5.80	39.99	3.09	27.76	30.000	11.901	0.94	6.49	1.35	12.11
12.000	4.760	4.95	34.15	2.92	26.24	31.000	12.298	0.89	6.12	1.28	11.47
13.000	5.157	4.28	29.54	2.78	24.98	32.000	12.694	0.84	5.77	1.21	10.84
14.000	5.554	3.75	25.83	2.66	23.91	33.000	13.091	0.79	5.46	1.14	10.23
15.000	5.950	3.31	22.79	2.56	22.96	34.000	13.488	0.75	5.17	1.07	9.65
16.000	6.347	2.94	20.28	2.46	22.10	35.000	13.884	0.71	4.91	1.01	9.08
17.000	6.744	2.63	18.17	2.37	21.29	36.000	14.281	0.68	4.66	0.95	8.53
18.000	7.141	2.38	16.38	2.29	20.52	37.000	14.678	0.64	4.44	0.89	8.00
19.000	7.537	2.15	14.85	2.20	19.77	38.000	15.075	0.61	4.23	0.83	7.49
20.000	7.934	1.96	13.53	2.12	19.04	39.000	15.471	0.59	4.03	0.78	7.01
21.000	8.331	1.80	12.39	2.04	18.32	40.000	15.868	0.56	3.85	0.73	6.55

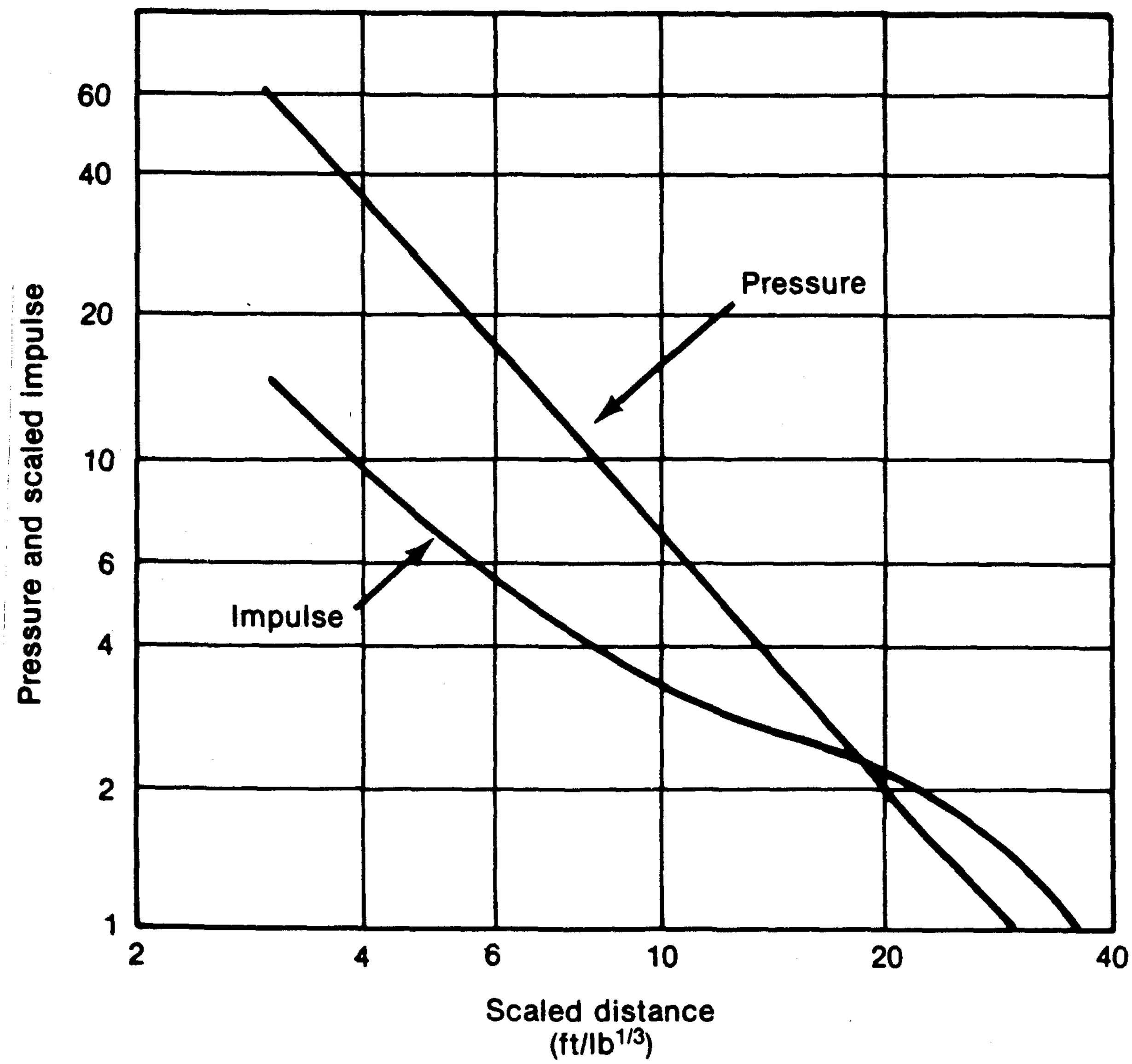


Figure 99. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for Benite Propellant in Orthorhombic Containers, L/D=1:1.

BS-NACO PROPELLANT[26]

OBJECTIVE

The objective of this study was to experimentally determine the maximum peak pressure and scaled positive impulse of BS-NACO propellant and to determine the TNT eqivalency by comparing the measured values to hemispherical TNT surface bursts.

MATERIAL

BS-NACO multiperforated 1.291 mm (0.048 inch) web size propellant was tested in cardboard drums, full-sized metal shipping containers, and aluminum hoppers.

TEST SETUP

Three configurations were tested. Cylindrical cardboard containers constructed from fiberboard and filled with 22.7 kg (50 lb) of propellant. A full-size orthorhombic metal shipping container filled with 49.9 kg (110 lb) of propellant. The metal container offered heavy confinement to the test charge. A full-scale aluminum hopper filled with 149.7 kg (330 lb) of propellant was the third configuration.

All test configurations were initiated with a Composition C4 booster and a J2 engineers' special blasting cap.

INSTRUMENTATION

Instrumentation setup was similar to the setup described in the chapter entitled "Nitroglycerine".

RESULTS

The cylindrical configuration test results are shown in Table 53 and Figure 100. The orthorhombic shipping container configurtation results are given in Table 54 and Figure 101. The truncated prism configuration test results are given in Table 55 and Figure 102.

DISCUSSION

The peak pressure values for the BS-NACO propellant in 22.7 Kg (50 lb) cylindrical containers were less than expected at all scale distances of the experiment. The pressure values were 374, 197, 105, 40, 13, and 5 kPa (54.30, 28.51, 15.22, 5.80, 1.93, and 0.73 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0 and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 0.2, 0.2, 0.2, 0.3, 0.3, 0.2, and 0.2 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were less than expected at all scaled distances of the experiment. The scaled positive impulse values were 78, 61, 47, 31, 17, and 8.8 $kPa\text{-}ms/kg^{1/3}$ (8.64, 6.79, 5.27, 3.43, 1.92, and 1.02 $psi\text{-}ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87

m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.3, 0.3, 0.1, 0.3, 0.3, and 0.3 times equal amounts of TNT at the same scaled distances respectively.

The pressure values for the orthorhombic metal shipping container were less than expected at all scaled distances of the experiment. The peak pressure values were 304, 168, 90, 31, 7.0, and 1.24 kPa (44.05, 24.44, 13.11, 4.47, 1.01, and 0.18 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 0.2, 0.2, 0.2, 0.3, 0.1, and 0.1 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were less than expected at all scaled distances of the experiment. The scaled positive impulse values were 78, 56, 39, 22, 10, and 4.46 kPa-ms/kg$^{1/3}$ (8.74, 6.21, 4.37, 2.44, 1.14, and 0.52 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.4, 0.3, 0.2, 0.2, 0.2, and 0.1 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the 149.7 kg (330 lb) BS-NACO propellant in the truncated prism configuration were less than expected at all scaled distances of the experiment. The peak pressure values were 399, 216, 117, 44, 13, and 4.1 kPa (57.85, 31.26, 17.02, 6.42, 1.94, and 0.59 psi) at scaled distance 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 0.3, 0.3, 0.3, 0.3, 0.3, and 0.2 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were less than expected at all scaled distances of the experiment. The scaled positive impulse values were 111, 88, 68, 42, 21, and 8.5 kPa-ms/kg$^{1/3}$ (12.36, 9.79, 7.56, 4.72, 2.33, and 0.94 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0 and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.5, 0.5, 0.5, 0.4, 0.4, and 0.4 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) BS-NACO propellant failed to mass detonate when initiated with as much as a 10% booster.

(2) BS-NACO propellant did not scale as a function of the cube root of the charge weight. This was due in part to the lack of mass detonation.

(3) BS-NACO propellant had a TNT equivalency significantly less than equal amounts of TNT at all scaled distances of the experiment.

Table 53. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for BS-NACO Propellant in Cylindrical Configuration.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	54.28	374.26	8.64	77.58	22.000	8.727	1.46	10.09	1.62	14.53
4.000	1.587	28.51	196.60	6.79	60.92	23.000	9.124	1.38	9.52	1.56	14.00
5.000	1.983	17.80	122.75	5.63	50.50	24.000	9.521	1.31	9.01	1.51	13.51
6.000	2.380	12.34	85.09	4.83	43.32	25.000	9.917	1.24	8.56	1.45	13.05
7.000	2.777	9.17	63.23	4.24	38.06	26.000	10.314	1.18	8.15	1.41	12.63
8.000	3.174	7.16	49.36	3.79	34.02	27.000	10.711	1.13	7.78	1.36	12.24
9.000	3.570	5.80	39.97	3.43	30.81	28.000	11.108	1.08	7.45	1.32	11.87
10.000	3.967	4.83	33.29	3.14	28.20	29.000	11.504	1.04	7.14	1.28	11.52
11.000	4.364	4.11	28.31	2.90	26.03	30.000	11.901	1.00	6.86	1.25	11.20
12.000	4.760	3.56	24.57	2.70	24.19	31.000	12.298	0.96	6.61	1.21	10.89
13.000	5.157	3.14	21.62	2.52	22.63	32.000	12.694	0.92	6.37	1.18	10.61
14.000	5.554	2.79	19.26	2.37	21.25	33.000	13.091	0.89	6.16	1.15	10.34
15.000	5.950	2.51	17.33	2.23	20.06	34.000	13.488	0.86	5.96	1.12	10.08
16.000	6.347	2.28	15.74	2.12	19.00	35.000	13.884	0.84	5.77	1.10	9.84
17.000	6.744	2.09	14.41	2.01	18.05	36.000	14.281	0.81	5.60	1.07	9.61
18.000	7.141	1.93	13.27	1.92	17.21	37.000	14.678	0.79	5.44	1.05	9.39
19.000	7.537	1.78	12.30	1.83	16.44	38.000	15.075	0.77	5.29	1.02	9.18
20.000	7.934	1.66	11.46	1.75	15.75	39.000	15.471	0.75	5.15	1.00	8.98
21.000	8.331	1.56	10.73	1.68	15.11	40.000	15.868	0.73	5.01	0.98	8.79

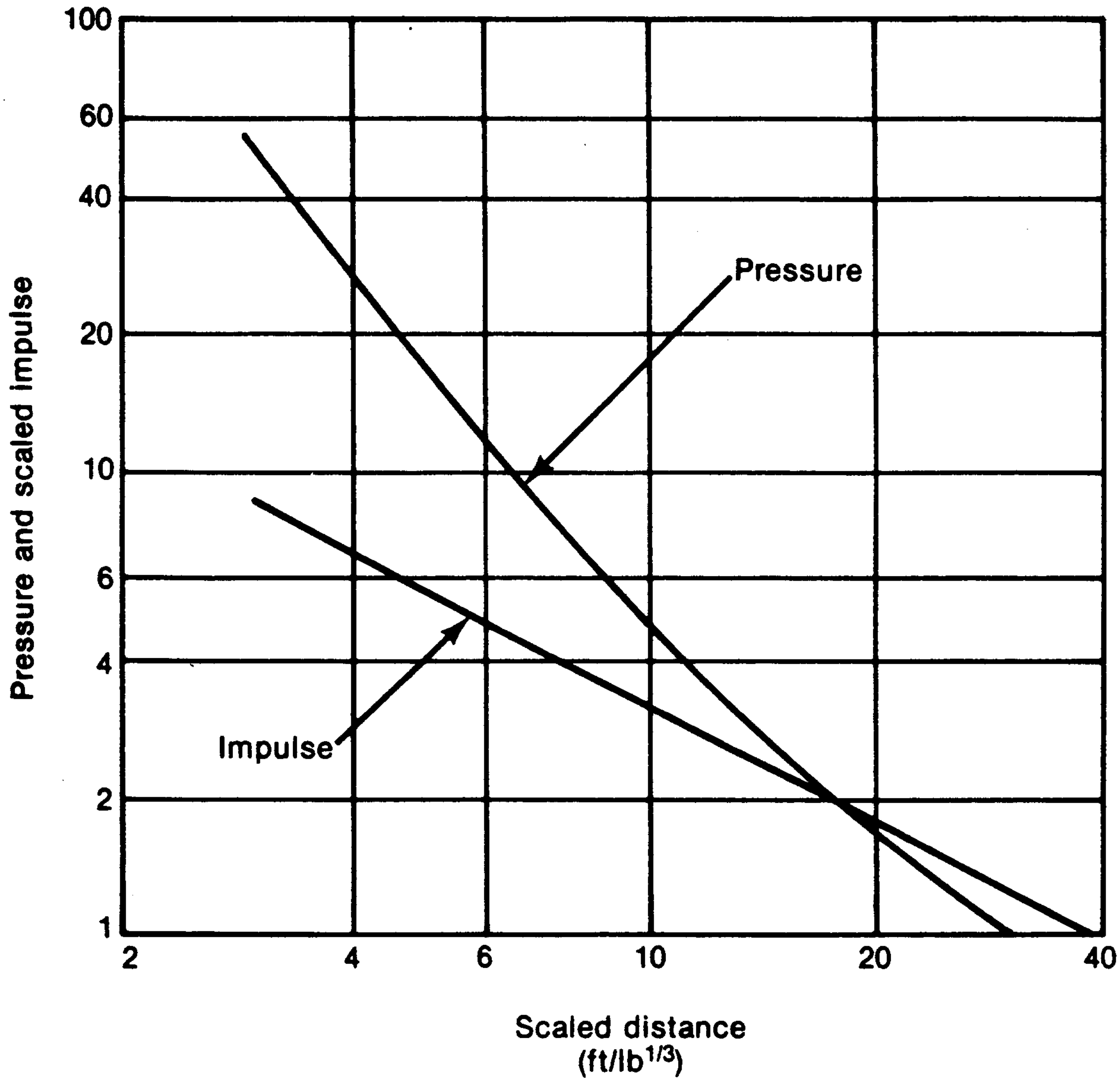


Figure 100. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for BS-NACO Propellant in Cylindrical Configuration.

Table 54. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for BS-NACO Propellant in Orthorhombic Configuration, L/D=1:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	44.05	303.69	8.74	78.43	22.000	8.727	0.66	4.53	0.92	8.28
4.000	1.587	24.44	168.49	6.21	55.69	23.000	9.124	0.60	4.11	0.88	7.90
5.000	1.983	15.39	106.11	4.78	42.87	24.000	9.521	0.54	3.75	0.84	7.56
6.000	2.380	10.52	72.50	3.87	34.72	25.000	9.917	0.50	3.43	0.81	7.24
7.000	2.777	7.60	52.44	3.24	29.10	26.000	10.314	0.46	3.15	0.77	6.95
8.000	3.174	5.64	39.55	2.79	25.01	27.000	10.711	0.42	2.91	0.74	6.68
9.000	3.570	4.47	30.81	2.44	21.91	28.000	11.108	0.39	2.69	0.72	6.43
10.000	3.967	3.57	24.62	2.17	19.47	29.000	11.504	0.36	2.49	0.69	6.20
11.000	4.364	2.91	20.09	1.95	17.52	30.000	11.901	0.34	2.31	0.67	5.99
12.000	4.760	2.42	16.68	1.77	15.92	31.000	12.298	0.31	2.15	0.65	5.79
13.000	5.157	2.04	14.06	1.62	14.58	32.000	12.694	0.29	2.01	0.62	5.60
14.000	5.554	1.74	11.99	1.50	13.45	33.000	13.091	0.27	1.88	0.61	5.43
15.000	5.590	1.50	10.34	1.39	12.47	34.000	13.488	0.26	1.76	0.59	5.27
16.000	6.347	1.31	9.00	1.30	11.63	35.000	13.884	0.24	1.66	0.57	5.11
17.000	6.744	1.15	7.90	1.21	10.90	36.000	14.281	0.23	1.56	0.55	4.97
18.000	7.141	1.01	6.98	1.14	10.25	37.000	14.678	0.21	1.47	0.54	4.83
19.000	7.537	0.90	6.21	1.08	9.68	38.000	15.075	0.20	1.39	0.52	4.70
20.000	7.934	0.81	5.56	1.02	9.16	39.000	15.471	0.19	1.31	0.51	4.58
21.000	8.331	0.73	5.01	0.97	8.70	40.000	15.868	0.18	1.24	0.50	4.46

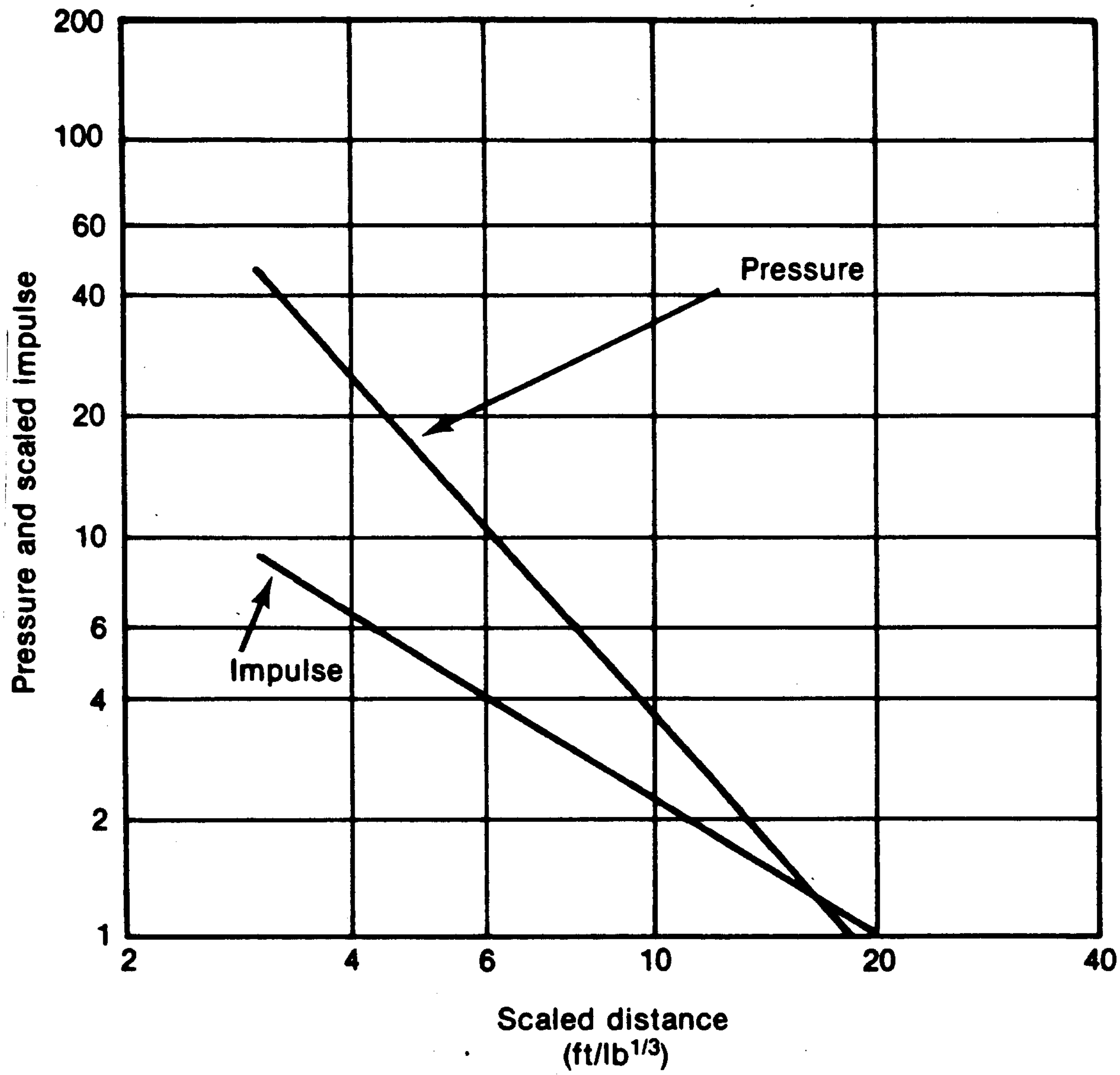


Figure 101. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for BS-NACO Propellant in Orthorhombic Configuration.

Table 55. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for BS-NACO Propellant in Hoppers (Truncated Prism).

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	57.85	398.88	12.36	110.96	22.000	8.727	1.42	9.76	1.88	16.84
4.000	1.587	31.36	216.23	9.79	87.81	23.000	9.124	1.32	9.11	1.79	16.04
5.000	1.983	19.85	136.89	8.09	72.59	24.000	9.521	1.24	8.54	1.70	15.29
6.000	2.380	13.82	95.32	6.88	61.78	25.000	9.917	1.16	8.03	1.63	14.61
7.000	2.777	10.26	70.76	5.98	53.68	26.000	10.314	1.10	7.57	1.56	13.98
8.000	3.174	7.98	54.99	5.28	47.39	27.000	10.711	1.04	7.15	1.49	13.40
9.000	3.570	6.42	44.23	4.72	42.36	28.000	11.108	0.98	6.78	1.43	12.85
10.000	3.967	5.30	36.54	4.26	38.24	29.000	11.504	0.93	6.44	1.38	12.35
11.000	4.364	4.47	30.83	3.88	34.81	30.000	11.901	0.89	6.13	1.32	11.88
12.000	4.760	3.84	26.47	3.56	31.91	31.000	12.298	0.85	5.84	1.27	11.44
13.000	5.157	3.34	23.05	3.28	29.43	32.000	12.694	0.81	5.58	1.23	11.03
14.000	5.554	2.95	20.32	3.04	27.27	33.000	13.091	0.77	5.34	1.19	10.64
15.000	5.950	2.62	18.09	2.83	25.39	34.000	13.488	0.74	5.12	1.14	10.27
16.000	6.347	2.36	16.25	2.64	23.73	35.000	13.884	0.71	4.91	1.11	9.93
17.000	6.744	2.13	14.71	2.48	22.26	36.000	14.281	0.69	4.72	1.07	9.61
18.000	7.141	1.94	13.41	2.33	20.94	37.000	14.678	0.66	4.55	1.04	9.30
19.000	7.537	1.78	12.30	2.20	19.76	38.000	15.075	0.64	4.38	1.00	9.01
20.000	7.934	1.64	11.33	2.08	18.69	39.000	15.471	0.61	4.23	0.97	8.74
21.000	8.331	1.52	10.50	1.98	17.73	40.000	15.868	0.59	4.08	0.94	8.48

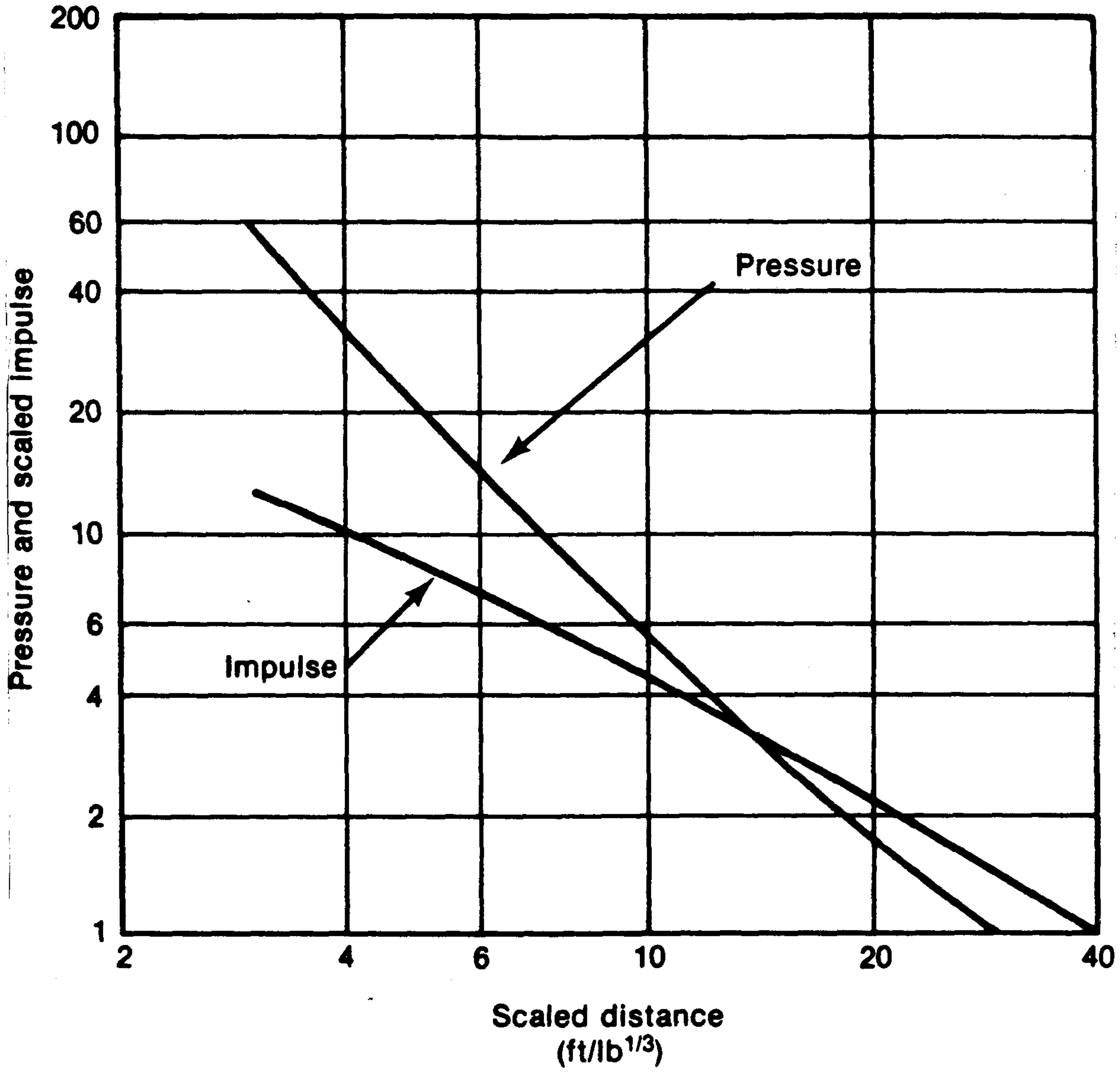


Figure 102. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for BS-NACO Propellant in Hoppers (Truncated Prism), L/D=1:1.

OBJECTIVE

The objective of these tests was to determine the maximum blast output from the detonation of DIGL-RP stick, double-base propellant (I5420, I5421 and I5422) in terms of airblast overpressure and positive impulse. The measured values were then compared to known hemispherical TNT surface burst data to determine TNT equivalency.

MATERIAL

The test material was DIGL-RP stick, double-base propellant with a material composition of nitrocellulose, diethyleneglycol dinitrate, Akardite II Antralite I, magnesium oxide and graphite. Propellant DIGL-RP I5420 stick size was 335.1 mm (13.98 inches) long by 6.0 mm (0.236 inch) in diameter. DIGL-RP I5421 stick size was 8.51 mm (3.35 inches) long by 6.0 mm (0.236 inch) in diameter. DIGL-RP I5422 stick size was 76.2 mm (3.0 inches) long by 6.0 mm (0.236 inch) in diameter.

TEST SETUP

The test material was evaluated in cylindrical and orthorhombic configurations. The physical characteristics of the test items were as follows:

(1) DIGL-RP I5420 in charge weights of 24.95, 49.90, and 74.58 kg (55, 110, and 165 lb) were tested in orthorhombic containers. The scaling factors were 0.69, 0.87, and 1.0, respectively. The containers were constructed from plywood.

(2) DIGL-RP I5421 in charge weights of 9.98, 19.96, and 29.94 kg (22, 44, and 66 lb) were tested in cylindrical containers. The scaling factors were 0.69, 0.87, and 1.0, respectively. The cylindrical containers were fiberboard.

(3) DIGL-RP I5422 with a charge weight of 9.07 kg (20 lb) was tested in a shipping case constructed from plywood, with a scaling factor of 0.5.

INSTRUMENTATION

Twelve side-on pressure transducers were mounted flush to the ground surface in two sand-filled runways in a 90-degree array. Distances from the charge to the transducers ranged from 1.19 to 15.87 $m/kg^{1/3}$ (3.0 to 40.0 $ft/lb^{1/3}$) and were held constant throughout the experiments.

RESULTS

The combined results of the DIGL-RP I5420 propellant tests in an orthorhombic configuration are given in Table 56 and Figure 103. The combined pressure and scaled positive impulse values for the DIGL-RP

I5421 propellant in cylindrical configruation are given in Table 57 and Figure 104. The pressure and scaled positive impulse values for the DIGL-RP I5422 results are given in Table 58 and Figure 105.

DISCUSSION

Peak pressure values for DIGL-RP I5420 propellant in an orthorhombic configuration were greater than equal amounts of TNT at all scaled distances of the experiment. The peak pressure values were 2454, 1329, 522, 104, 28, and 11.5 kPa (355.87, 192.74, 75.77, 15.12, 4.00, and 1.67 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 3.7, 4.1, 2.1, 1.3, 1.2, and 2.1 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were greater than expected at all scaled distances of the experiment. The scaled positive impulse values were 331, 197, 142, 101, 57, and 20.1 kPa-ms/$kg^{1/3}$ (36.88, 21.97, 15.86, 11.2, 6.32 and 2.24, psi-ms/$lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values for DIGL-RP I5420 propellant in an orthorhombic configuration equate to 2.9, 1.9, 1.5, 1.8, 1.9, and 1.2 times equal amounts of TNT at the same scaled distance, respectively.

The pressure values for DIGL-RP I5421 propellant in cylindrical containers were greater than expected at all scaled distances of the experiment. The pressure values were 1104, 620, 314, 107, 37, and 9.3 kPa (160.15, 89.94, 45.57, 15.55, 5.41, and 1.34 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 1.2, 1.5, 1.2, 1.4, 2.1, and 1.2 times equal amounts of TNT at the same scaled distance, respectively. Scaled positive impulse values were greater than expected at scaled distances of 1.19, 3.57 and 7.14 $m/kg^{1/3}$ (3.0, 9.0, and 18.0 $ft/lb^{1/3}$) and less than expected at scaled distances of 1.59, 2.14, and 15.87 $m/kg^{1/3}$ (4.0, 5.4, and 40.0 $ft/lb^{1/3}$). The scaled positive impulse values were 256, 132, 106, 100, 52, and 15.02 kPa-ms/$kg^{1/3}$ (28.47, 14.69, 11.84, 11.11, 5.76, and 1.67 psi-ms/$lb^{1/3}$) respectively. These scaled positive impulse values equate to 2.1, 0.9, 1.0, 1.8, 1.7, and 0.8 times equal amounts of TNT at the same scaled distances, respectively.

The peak pressure values for the DIGL-RP I5422 propellant in an orthorhombic configuration were greater than expected at scaled distances of 1.19, 1.59, 2.14, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 18.0, and 40.0 $ft/lb^{1/3}$) and less than expected at a scaled distance of 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$). The peak pressure values were 1782, 781, 294, 75, 33, and 10.39 kPa (258.50, 113.22, 42.70, 10.81, 4.76, and 1.51 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/l^{1/3}$), respectively. These pressure values equate to 2.3, 1.9, 1.1, 0.8, 1.6, and 1.6 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values for DIGL-RP I5422 were greater than expected at all scaled distances equal to or less than 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$) and less than expected at a scaled distance of 15.87 $m/kg^{1/3}$ (40.0 $ft/lb^{1/3}$). The scaled positive impulse values were 226, 154, 116, 83, 49, and 15.5 kPa-ms/kg$^{1/3}$ (25.14, 17.11, 12.94, 9.21, 5.43, and 1.72 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14 and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 1.5, 1.2, 1.0, 1.3, 1.5, and 0.8 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) DIGL-RP propellant, when detonated, can generate peak pressure and positive impulse values which are greater than those produced by an equivalent weight of TNT.

(2) The blast output from DIGL-RP propellant is dependant upon the configuration from which it detonates.

(3) To within experimental limits, blast pressure and impulse scale as a cube root function of the charge weight.

Table 56. **Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for DIGL-RP I5420 Propellant in Orthorhombic Configuration, L/D=0.5:1.**

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	355.87	2543.73	36.88	330.99	22.000	8.727	3.28	22.65	5.01	44.92
4.000	1.587	192.74	1328.95	21.97	197.18	23.000	9.124	3.16	21.79	4.74	42.50
5.000	1.983	97.59	672.87	17.00	152.55	24.000	9.521	3.05	21.02	4.49	40.26
6.000	2.380	53.37	367.97	14.60	130.98	25.000	9.917	2.94	20.31	4.26	38.19
7.000	2.777	32.19	221.98	13.12	117.78	26.000	10.314	2.85	19.64	4.04	36.26
8.000	3.174	21.24	146.48	12.06	108.23	27.000	10.711	2.76	19.00	3.84	34.48
9.000	3.570	15.12	104.23	11.20	100.52	28.000	11.108	2.67	18.39	3.66	32.83
10.000	3.967	11.44	78.89	10.46	93.84	29.000	11.504	2.58	17.79	3.49	31.30
11.000	4.364	9.10	62.75	9.79	87.85	30.000	11.901	2.50	17.21	3.33	29.83
12.000	4.760	7.54	51.97	9.18	82.35	31.000	12.298	2.41	16.63	3.18	28.55
13.000	5.157	6.45	44.45	8.61	77.26	32.000	12.694	2.33	16.05	3.05	27.33
14.000	5.554	5.66	39.03	8.08	75.23	33.000	13.091	2.24	15.48	2.92	26.19
15.000	5.590	5.08	35.00	7.59	68.13	34.000	13.488	2.16	14.90	2.80	25.12
16.000	6.347	4.63	31.92	7.14	64.03	35.000	13.884	2.08	14.33	2.69	24.14
17.000	6.744	4.28	29.52	6.71	60.22	36.000	14.281	2.00	13.76	2.59	23.21
18.000	7.141	4.00	27.60	6.32	56.68	37.000	14.678	1.91	13.19	2.49	22.36
19.000	7.537	3.77	26.03	5.95	53.40	38.000	15.075	1.83	12.62	2.40	21.56
20.000	7.934	3.59	24.72	5.61	50.36	39.000	15.471	1.75	12.06	2.32	20.81
21.000	8.331	3.42	23.61	5.30	47.54	40.000	15.868	1.67	11.50	2.24	20.11

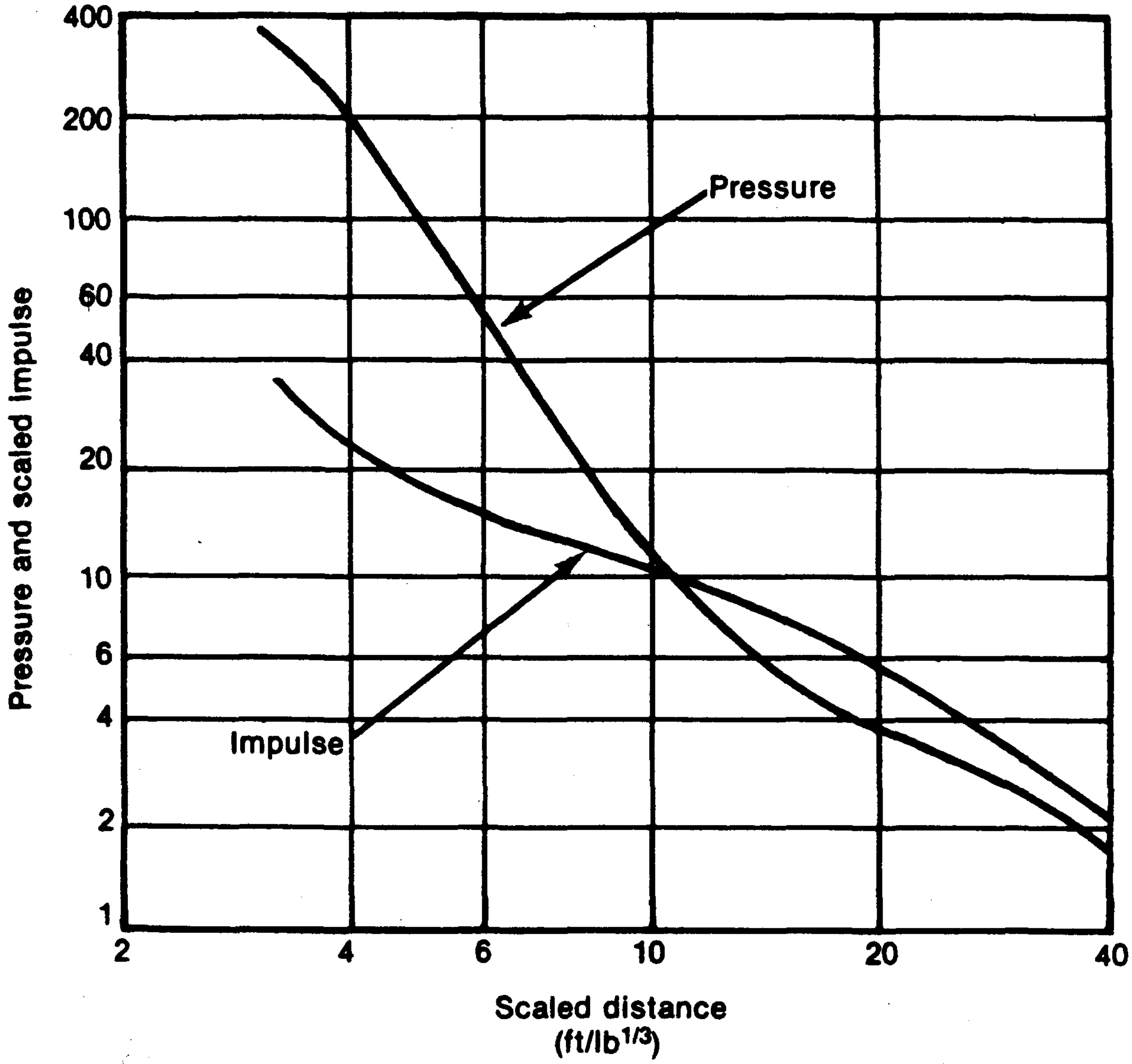


Figure 103. Peak Pressure and Scaled Positive Versus Scaled Distance for DIGL-RP I5420 Propellant in Orthorhombic Configuration, L/D=0/5:1.

Table 57. Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for DIGL-RP I5421 Propellant in Cylindrical Containers, L/D=1.1:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	160.15	1104.21	28.47	255.53	22.000	8.727	4.15	28.63	4.07	36.51
4.000	1.587	89.94	620.12	14.69	131.78	23.000	9.124	3.91	26.93	3.75	33.66
5.000	1.983	54.32	374.54	12.16	109.14	24.000	9.521	3.68	25.35	3.47	31.14
6.000	2.380	35.93	247.72	11.61	104.21	25.000	9.917	3.46	23.87	3.22	28.90
7.000	2.777	25.68	177.04	11.49	103.15	26.000	10.314	3.26	22.49	3.00	26.91
8.000	3.174	19.51	134.54	11.37	102.04	27.000	10.711	3.07	21.19	2.80	25.16
9.000	3.570	15.55	107.23	11.11	99.71	28.000	11.108	2.89	19.96	2.63	23.61
10.000	3.967	12.86	88.68	10.70	96.00	29.000	11.504	2.73	18.79	2.48	22.25
11.000	4.364	10.95	75.49	10.16	91.16	30.000	11.901	2.57	17.69	2.35	21.05
12.000	4.760	9.53	65.72	9.53	85.56	31.000	12.298	2.41	16.64	2.23	19.99
13.000	5.157	8.45	58.24	8.87	79.57	32.000	12.694	2.27	15.64	2.12	19.06
14.000	5.554	7.59	52.34	8.19	73.49	33.000	13.091	2.13	14.69	2.03	18.25
15.000	5.950	6.90	47.56	7.53	67.54	34.000	13.488	2.00	13.79	1.95	17.54
16.000	6.347	6.32	43.59	6.89	61.87	35.000	13.884	1.88	12.94	1.89	16.93
17.000	6.744	5.84	40.23	6.31	56.59	36.000	14.281	1.76	12.12	1.83	16.40
18.000	7.141	5.41	37.33	5.76	51.72	37.000	14.678	1.65	11.35	1.78	15.96
19.000	7.537	5.05	34.79	5.27	47.29	38.000	15.075	1.54	10.62	1.74	15.58
20.000	7.934	4.72	32.53	4.82	43.30	39.000	15.471	1.44	9.92	1.70	15.27
21.000	8.331	4.42	30.49	4.43	39.71	40.000	15.868	1.34	9.26	1.67	15.02

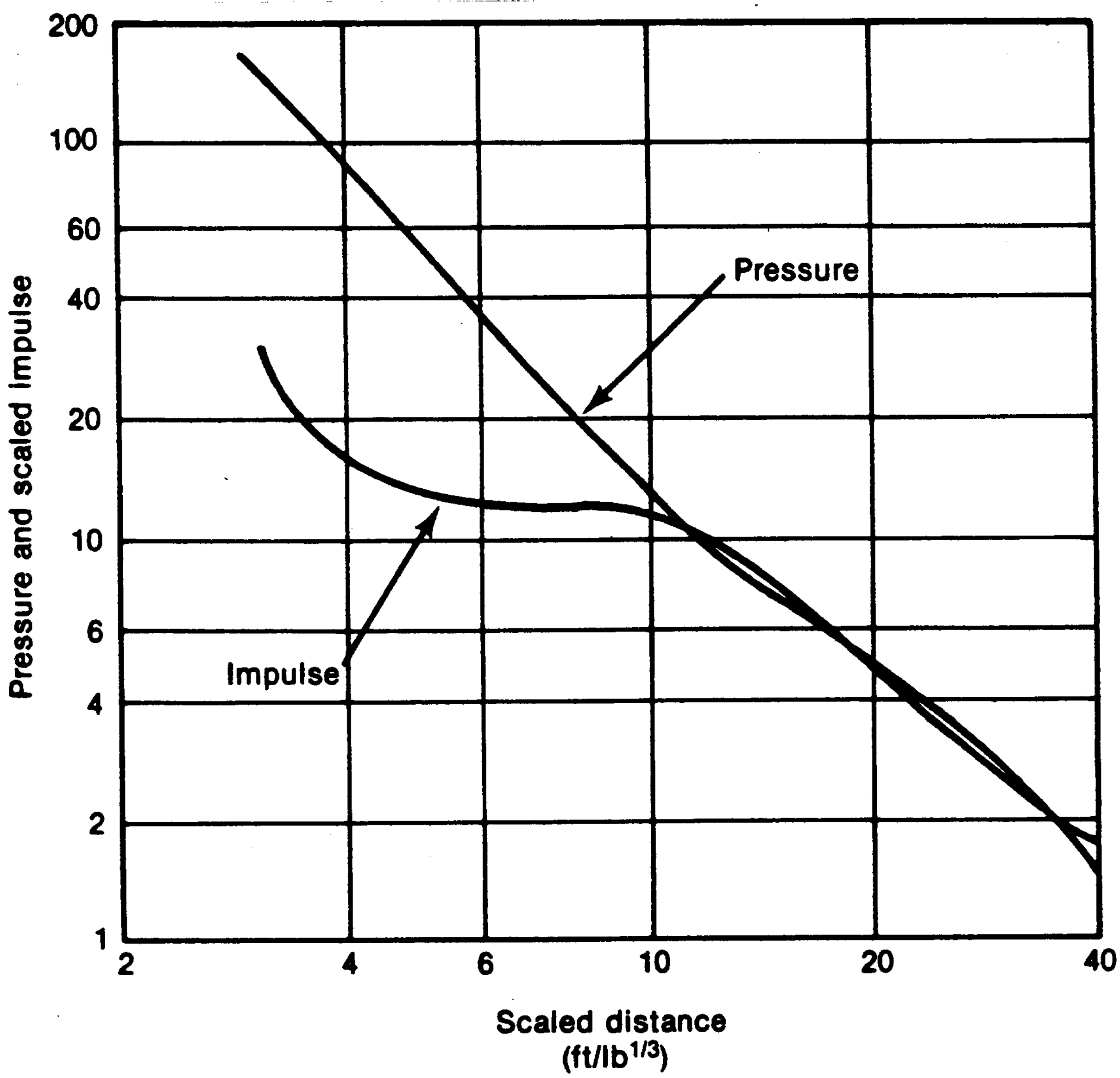


Figure 104. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for DIGL-RP I5421 Propellant in Cylindrical Containers, L/D=1.1:1.

Table 58. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for DIGL-RP I5422 Propellant in Orthorhombic Configuration, L/D=0.5:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	258.50	1782.39	25.14	225.64	22.000	8.727	4.21	29.04	4.36	39.13
4.000	1.587	113.22	780.65	17.11	153.56	23.000	9.124	4.08	28.15	4.13	37.06
5.000	1.983	54.72	377.31	13.78	123.69	24.000	9.521	3.95	27.24	3.91	35.11
6.000	2.380	30.75	212.02	11.97	107.38	25.000	9.917	3.81	26.29	3.71	33.27
7.000	2.777	19.71	135.92	10.78	96.75	26.000	10.314	3.67	25.32	3.51	31.54
8.000	3.174	14.02	96.69	9.91	88.93	27.000	10.711	3.52	24.30	3.33	29.91
9.000	3.570	10.81	74.50	9.21	82.67	28.000	11.108	3.37	23.26	3.16	28.37
10.000	3.967	8.85	61.00	8.62	77.37	29.000	11.504	3.22	22.18	3.00	26.92
11.000	4.364	7.58	52.29	8.10	72.69	30.000	11.901	3.06	21.08	2.85	25.55
12.000	4.760	6.73	46.42	7.63	68.47	31.000	12.298	2.90	19.96	2.70	24.26
13.000	5.157	6.13	42.30	7.20	64.59	32.000	12.694	2.73	18.84	2.57	33.05
14.000	5.554	5.70	39.32	6.80	60.99	33.000	13.091	2.57	17.71	2.44	21.90
15.000	5.950	5.38	37.08	6.42	57.63	34.000	13.488	2.41	16.59	2.32	20.82
16.000	6.347	5.13	35.35	6.07	54.48	35.000	13.884	2.25	15.49	2.21	19.39
17.000	6.744	4.92	33.96	5.74	51.52	36.000	14.281	2.09	14.40	2.10	18.83
18.000	7.141	4.76	32.79	5.43	48.74	37.000	14.678	1.94	13.34	2.00	17.92
19.000	7.537	4.61	31.76	5.14	46.12	38.000	15.075	1.79	12.32	1.90	17.06
20.000	7.934	4.47	30.82	4.86	43.65	39.000	15.471	1.64	11.33	1.81	16.24
21.000	8.331	4.34	29.92	4.60	41.32	40.000	15.868	1.51	10.39	1.72	15.47

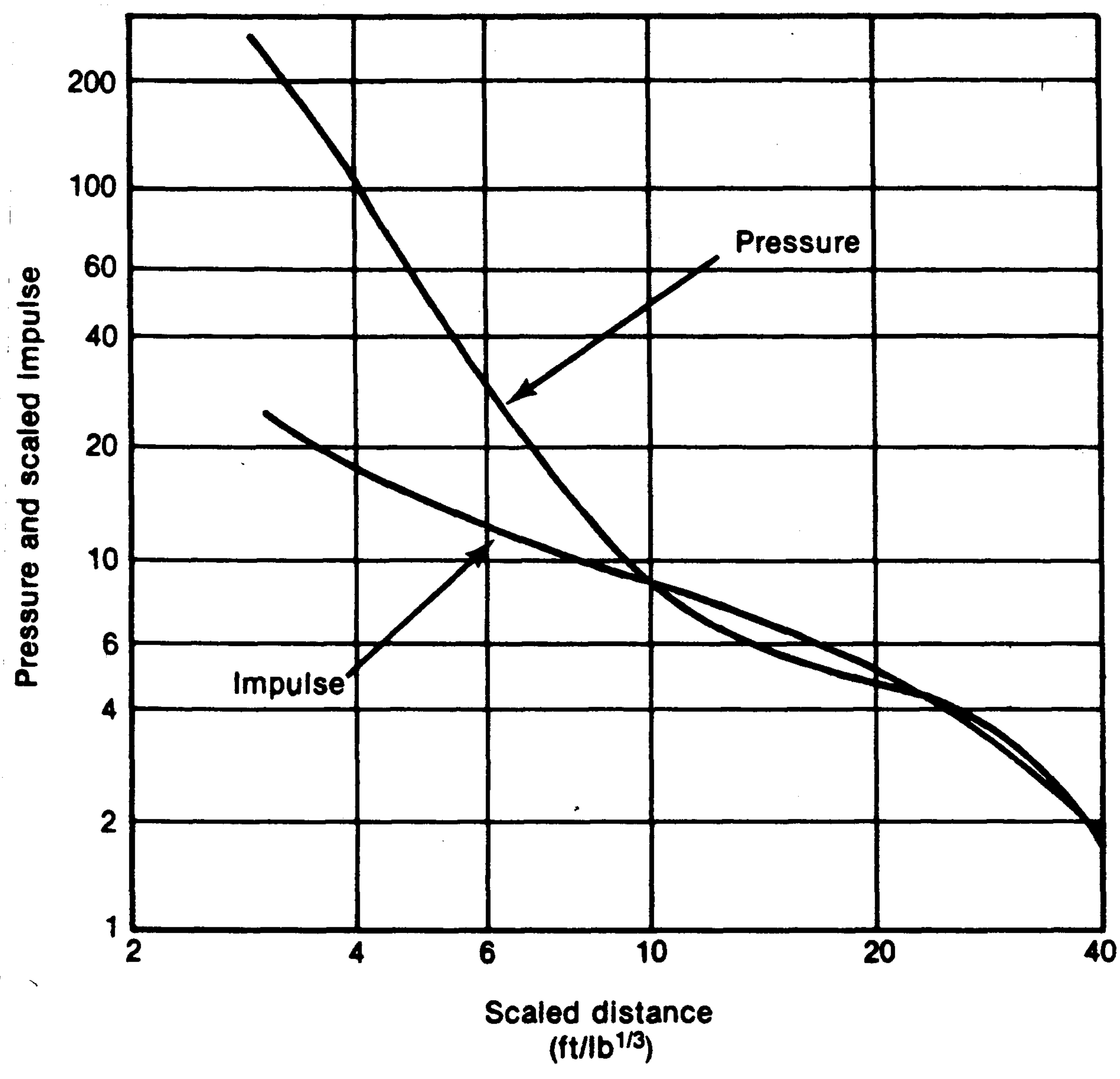


Figure 105. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for DIGL-RP I5422 Propellant in Orthorhombic Configuration, L/D=0.5:1.

OBJECTIVE

The objective of this work was to determine the maximum blast output from the detonation of JA-2 (L5460) double base propellant in terms of airblast overpressure and positive impulse. The measured pressure and impulse values were compared to hemispherical TNT surface burst data to determine TNT equivalency.

MATERIAL

JA-2 (15460) Propellant is a solventless multiperforated high-force propellant with a nominal composition of 60% nitrocellulose, 24.6% diethylene glycol dinitrate, 7.2% Akardite II, 7% magnesium oxide and 0.5% graphite. Physical dimensions of the propellant were 14.22 mm (0.56 inch) long by 8.94 mm (0.352 inch) inside diameter. Density of the grain was 1.59 g/cm^3.

TEST SETUP

JA-2 (5460) propellant was tested in cylindrical and orthorhombic configurations. The physical characteristics of the test articles were:

(1) A fiberboard cylindrical container with charge weights of 16.33, 33.11, and 49.90 kg (36, 73, and 110 lb) were tested. The scaling factor for each container was 0.7, 0.87, and 1.0 used in this test series.

(2) An orthorhombic fiberboard container representing a simulated dryer bed section was filled with charge weights of 24.95, 32.66, and 49.90 kg (55, 72, and 110 lb).

INSTRUMENTATION

Twelve side-on pressure transducers were flush mounted to the ground surface in two sand-filled runways in a 90-degree array. Scaled distances ranged from 1.19 to 15.87 m/kg$^{1/3}$ (3.0 to 40.0 ft/lb$^{1/3}$) and remained constant throughout the test series.

RESULTS

The combined results of all of the cylindrical charge weights are given in Table 59 and Figure 106. The results of the orthorhombic tests are given in Table 60 and Figure 107.

DISCUSSION

Peak pressure values for cylindrical JA-2 (L5460) propellant were greater than expected at all scaled distances of the experiment. The peak pressures were 1850, 957, 396, 104, 42, and 10.15 kPa (268.28, 138.85, 57.49, 15.11, 6.12, and 1.47 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and

40.o ft/lb$^{1/3}$), respectively. These pressure values equate to 2.8, 2.3, 2.0, 1.4, 2.7, and 1.6 times equal amounts of TNT at the same scaled distance, respectively. The scaled positive impulse values for the cylindrical JA-2 propellant in cylindrical configuration were equal to or greater than expected at all scaled distances of the experiment. The scaled positive impulse values were 300, 172, 141, 123, 59, and 17.2 kPa-ms/kg$^{1/3}$ (33.48, 19.16, 15.68, 13.69, 6.53, and 1.92 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 2.6, 1.4, 1.8, 1.9, 2.1, and 1.0 times equal amounts of TNT at the same scaled distances, respectively.

Peak pressure values for JA-2 Propellant in an orthorhombic configuration were greater than expected at scaled distances of 1.19, 1.59, 2.14, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 18.0, and 40.0 ft/lb$^{1/3}$) and less than expected at a scaled distance of 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$). The peak pressure values were 1449, 705, 293, 79, 32, and 10.8 kPa (210.18, 102.20, 42.46, 11.52, 4.60, and 1.56 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0 and 40.0, ft/lb$^{1/3}$), respectively. These pressure values equate to 1.8, 1.7, 1.1, 0.9, 1.6, and 1.7 times equal amounts of TNT at the same scale distances, respectively. Scale positive impulse values for JA-2 (L5460) in orthorhombic configuration were greater than expected at scaled distances of 1.19, 3.57, and 7.14 m/kg$^{1/3}$ (3.0, 9.0, and 18.0 ft/lb$^{1/3}$) and less than expected at scaled distances of 1.59, 2.14, and 15.87 m/kg$^{1/3}$ (4.0, 5.4, and 40.0 ft/lb$^{1/3}$). The scaled positive impulse values were 190, 132, 106, 79, 41, and 15.3 kPa-ms/kg$^{1/3}$ (21.14, 14.69, 11.81, 8.85, 4.59, and 1.70 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0 and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 1.1, 0.9, 0.9, 1.2, 1.1, and 0.8 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) JA-2 (L5460) propellant, when detonated can generate peak pressure values which are greater than those produced by equal amounts of TNT.

(2) The blast output from JA-2 (L5460) propellant is dependent upon the configurations from which it is detonated.

(3) To within experimental limits, blast overpressure and impulse scaled as a function of the cube root of the charge weight.

Table 59. **Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for JA-2 (L5460) Propellant in Cylindrical Configuration, L/D=1:1.**

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	268.28	1849.77	33.48	300.42	22.000	8.727	5.17	35.68	4.59	41.23
4.000	1.587	138.85	957.34	19.16	171.95	23.000	9.124	4.96	34.17	4.24	38.03
5.000	1.983	72.39	499.13	16.15	144.93	24.000	9.521	4.74	32.67	3.92	35.20
6.000	2.380	42.16	290.67	15.25	136.81	25.000	9.917	4.52	31.16	3.64	32.69
7.000	2.777	27.46	189.31	14.78	132.66	26.000	10.314	4.30	29.64	3.40	30.48
8.000	3.174	19.63	135.36	14.30	128.37	27.000	10.711	4.08	28.11	3.18	28.53
9.000	3.570	15.11	104.18	13.69	122.87	28.000	11.108	3.85	26.56	2.99	26.81
10.000	3.967	12.31	84.89	12.95	116.17	29.000	11.504	3.63	25.02	2.82	25.29
11.000	4.364	10.48	72.27	12.10	108.61	30.000	11.901	3.41	23.48	2.67	23.96
12.000	4.760	9.23	63.61	11.21	100.64	31.000	12.298	3.18	21.96	2.54	22.78
13.000	5.157	8.33	57.43	10.32	92.61	32.000	12.694	2.97	20.46	2.42	21.75
14.000	5.554	7.66	82.84	9.45	84.81	33.000	13.091	2.75	18.99	2.32	20.84
15.000	5.950	7.15	49.32	8.63	77.43	34.000	13.488	2.55	17.56	2.23	20.05
16.000	6.347	6.75	46.51	7.86	70.57	35.000	13.884	2.35	16.17	2.16	19.37
17.000	6.744	6.41	44.19	7.16	64.29	36.000	14.281	2.15	14.84	2.09	18.78
18.000	7.141	6.12	42.19	6.53	58.60	37.000	14.678	1.97	13.57	2.04	18.28
19.000	7.537	5.86	40.41	5.96	53.49	38.000	15.075	1.79	12.36	1.99	17.85
20.000	7.934	5.62	38.76	5.45	48.91	39.000	15.471	1.63	11.22	1.95	17.50
21.000	8.331	5.39	37.20	5.00	44.84	40.000	15.868	1.47	10.15	1.92	17.21

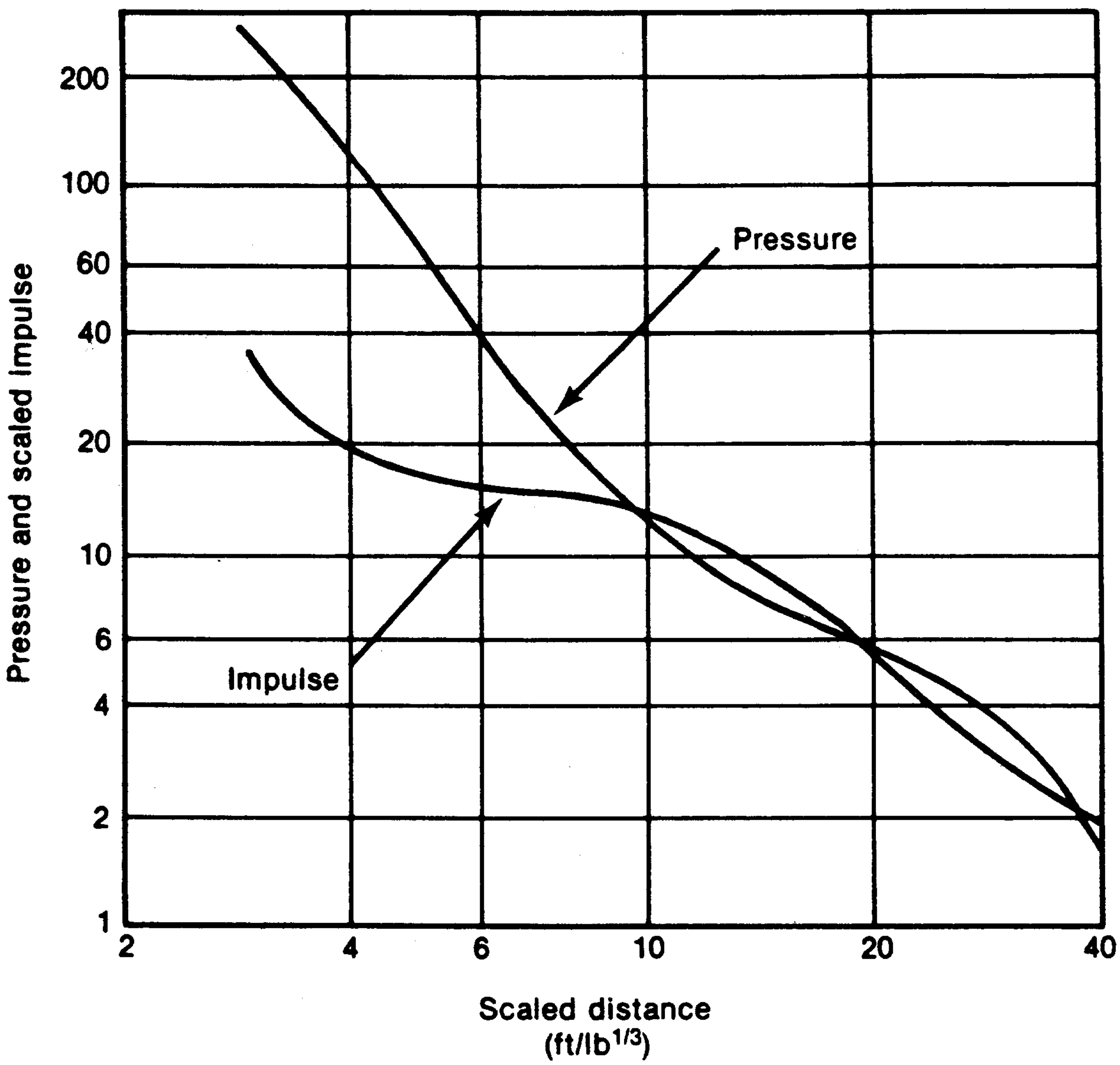


Figure 106. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for JA-2 (L5460) Propellant in Cylindrical Configuration, L/D=1:1.

Table 60. **Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for JA-2 (L5460) Propellant in Orthorhombic Configuration, L/D=0.25:1.**

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	210.18	1449.16	21.14	189.68	22.000	8.727	3.94	27.18	3.55	31.85
4.000	1.587	102.20	704.65	14.69	131.83	23.000	9.124	3.80	26.21	3.34	30.02
5.000	1.983	53.23	367.05	12.38	111.10	24.000	9.521	3.66	25.26	3.16	28.35
6.000	2.380	31.37	216.33	11.14	99.97	25.000	9.917	3.53	24.33	2.99	26.84
7.000	2.777	20.67	142.54	10.26	92.07	26.000	10.314	3.39	23.40	2.84	25.47
8.000	3.174	14.90	102.75	9.52	85.44	27.000	10.711	3.26	22.47	2.70	24.22
9.000	3.570	11.52	79.43	8.85	79.44	28.000	11.108	3.12	21.53	2.57	23.08
10.000	3.967	9.40	64.81	8.23	73.84	29.000	11.504	2.99	20.59	2.46	22.05
11.000	4.364	8.00	55.13	7.64	68.58	30.000	11.901	2.85	19.65	2.35	21.11
12.000	4.760	7.02	48.42	7.10	63.67	31.000	12.298	2.71	18.71	2.26	20.25
13.000	5.157	6.32	43.59	6.59	59.11	32.000	12.694	2.58	17.77	2.17	19.47
14.000	5.554	5.80	39.99	6.12	54.88	33.000	13.091	2.24	16.84	2.09	18.75
15.000	5.950	5.40	37.23	5.68	51.00	34.000	13.488	2.31	15.91	2.02	18.16
16.000	6.347	5.08	35.03	5.29	47.44	35.000	13.884	2.18	15.00	1.95	17.51
17.000	6.744	4.82	33.24	4.92	44.19	36.000	14.281	2.05	14.11	1.89	16.97
18.000	7.141	4.60	31.74	4.59	41.23	37.000	14.678	1.92	13.23	1.84	16.48
19.000	7.537	4.41	30.43	4.29	38.54	38.000	15.075	1.80	12.38	1.79	16.03
20.000	7.934	4.24	29.26	4.02	36.09	39.000	15.471	1.67	11.55	1.74	15.62
21.000	8.331.	4.09	28.19	3.77	33.87	40.000	15.868	1.56	10.75	1.70	15.26

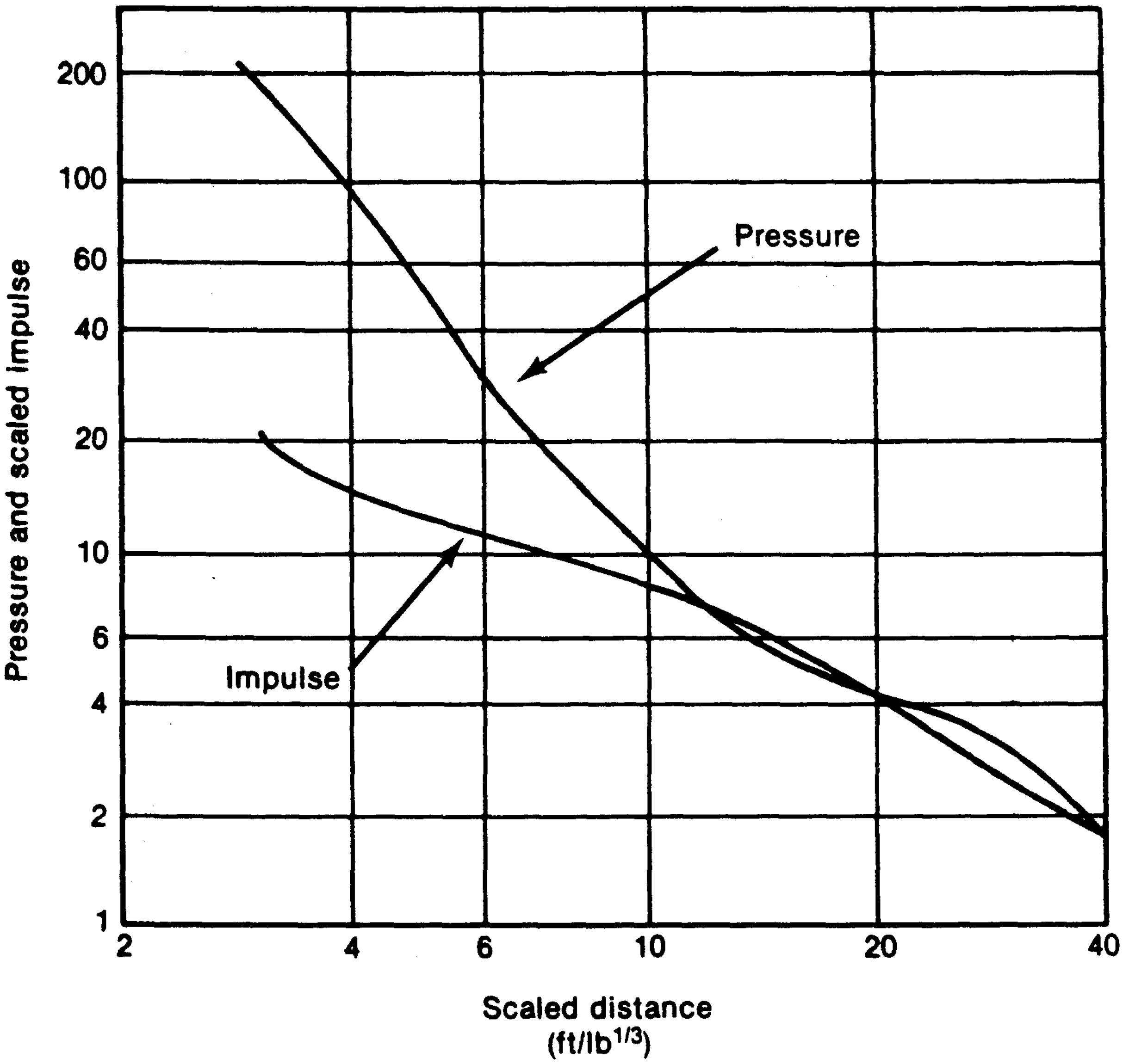


Figure 107. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for JA-2 (L5460) Propellant in Orthorhombic Configuration, L/D=0.25:1.

M1 PROPELLANT(29)

OBJECTIVE

The objective of this work was to experimentally determine the maximum output from the detonation of two M1 propellant granulations in terms of their airblast overpressure and impulse. The blast parameters in terms of pressure and impulse were compared to known characteristics of hemisperical surface burst TNT data and TNT equivalency for M1 propellant was determined.

TEST MATERIAL

M1 propellant is a single base propellant consisting of 84.2%, 13.15% N nitrocellulose; 9.9% dinitrotoluene; 4.9% dibutylphthalate; and 1.0% diphenylamine. Two granulations were tested. The first was single perforated, 0.33 mm (0.013 inch) web size and the second was multi-perforated with 0.635 mm (0.025 inch) web size.

TEST SETUP

Three basic configurations were tested. The first simulation consisted of scaled cardboard drums that dimensionally represented the actual shipping drum. The second configuration was a truncated prism representing an open feed hopper. The third configuration represented a closed feed hopper.

INSTRUMENTATION

The instrumentation system used in these experiments is similar to the IITRI system described in the chapter entitled "INSTRUMENTATION".

RESULTS

The results of the M1 single perforated propellant are given in Table 61 and Figure 108. The combined results of the M1 multiperforated propellant are given in Table 62 and Figure 109.

DISCUSSION

The pressure values for M1 single perforated propellant were less than expected at all scaled distances of the experiment. The pressure values were 448, 288, 181, 73, 12.52, and 0.46 kPa (65.40, 41.78 26.32, 10.61, 1.82, and 0.1 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 0.3, 0.3 0.5, 0.6, 0.7, and 0.1 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values for the single perforated propellant were less than expected at all scaled distances of the experiment. The scaled positive impulse values were 96.7, 84.6, 74.6, 58.4, 18.1, and 0.08 kPa-ms/kg$^{1/3}$ (10.77, 9.43, 8.31, 6.48, 2.01, and 0.01 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.4, 0.4, 0.5, 0.7, 0.7, and 0.1 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the multiperforated propellant were less than expected at all scaled distances of the experiment. The pressure values were 592, 288, 146, 52, 16, and 6.07 kPa (85.91, 41.86, 21.10, 7.53, 2.37, and 0.88 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 71.4, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 0.6, 0.5, 0.5, 0.5, 0.4, and 0.6 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values for the multiperforated propellant were less tha expected at all scaled distances of the experiment. The scaled positive impulse values were 151, 108, 78, 46, 24, and 13.15 kPa-ms/kg$^{1/3}$ (16.87, 12.11, 8.67, 5.08, 2.67, and 1.47 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.8, 0.7, 0.6, 0.5, 0.5, and 0.7 times equal amounts of TNT at the same scaled distances, repectively.

CONCLUSIONS

(1) M1 single-perforated propellant had higher pressure and scaled positive impulse values greater than multiperforated test.

(2) Both single and multiperforated propellant detonated and blast pressures and positive impulse values were less than equal amounts of TNT at the same scaled distances respectively.

Table 61. **Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for Combined Values of Single-perforated for M1 Propellant.**

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	64.50	444.70	10.77	96.68	22.000	8.727	0.92	6.34	0.92	8.29
4.000	1.587	41.74	287.81	9.43	84.61	23.000	9.124	0.78	5.39	0.75	6.69
5.000	1.983	29.70	204.81	8.57	76.95	24.000	9.521	0.67	4.59	0.60	5.37
6.000	2.380	22.19	152.97	7.97	71.52	25.000	9.917	0.57	3.92	0.48	4.28
7.000	2.777	17.05	117.58	7.46	66.97	26.000	10.314	0.49	3.35	0.38	3.39
8.000	3.174	13.36	92.11	6.98	62.61	27.000	10.711	0.42	2.87	0.30	2.67
9.000	3.570	10.61	73.13	6.48	58.14	28.000	11.108	0.36	2.47	0.23	2.09
10.000	3.967	8.51	58.67	5.96	53.46	29.000	11.504	0.31	2.12	0.18	1.63
11.000	4.364	6.88	47.46	5.42	48.60	30.000	11.901	0.27	1.83	0.14	1.27
12.000	4.760	5.61	38.66	4.87	43.66	31.000	12.298	0.23	1.58	0.11	0.98
13.000	5.157	4.59	31.67	4.32	38.75	32.000	12.694	0.20	1.37	0.08	0.76
14.000	5.554	3.78	26.09	3.79	34.00	33.000	13.091	0.17	1.19	0.06	0.58
15.000	5.950	3.13	21.59	3.29	29.49	34.000	13.488	0.15	1.03	0.05	0.44
16.000	6.347	2.60	17.94	2.82	25.30	35.000	13.884	0.13	0.90	0.04	0.34
17.000	6.744	2.17	14.96	2.39	21.49	36.000	14.281	0.11	0.78	0.03	0.24
18.000	7.141	1.82	12.52	2.01	18.07	37.000	14.678	0.10	0.68	0.02	0.19
19.000	7.537	1.53	10.52	1.68	15.06	38.000	15.075	0.09	0.60	0.02	0.15
20.000	7.934	1.28	8.86	1.39	12.44	39.000	15.471	0.08	0.52	0.01	0.11
21.000	8.331	1.09	7.49	1.14	10.19	40.000	15.868	0.07	0.46	0.01	0.08

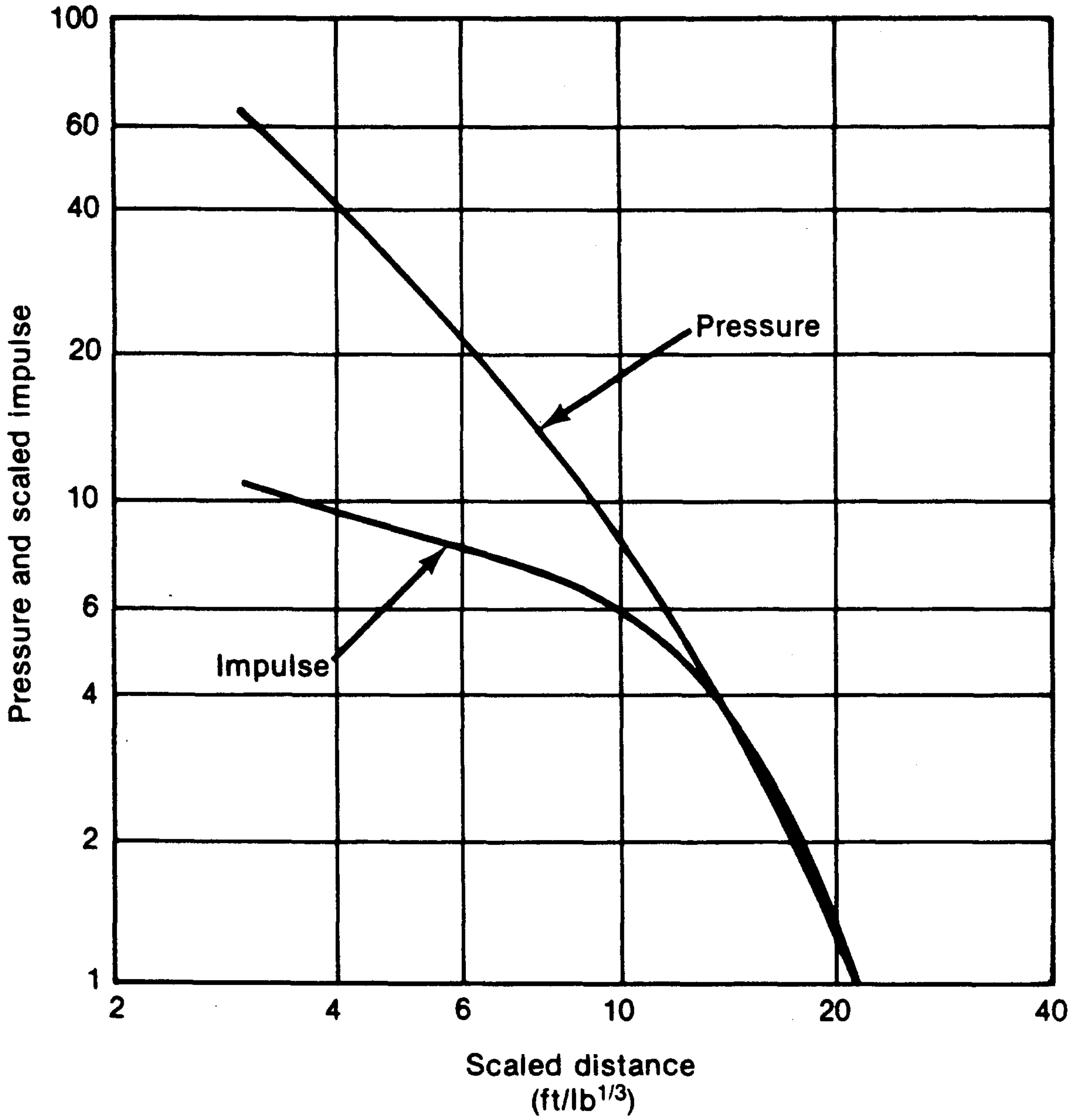
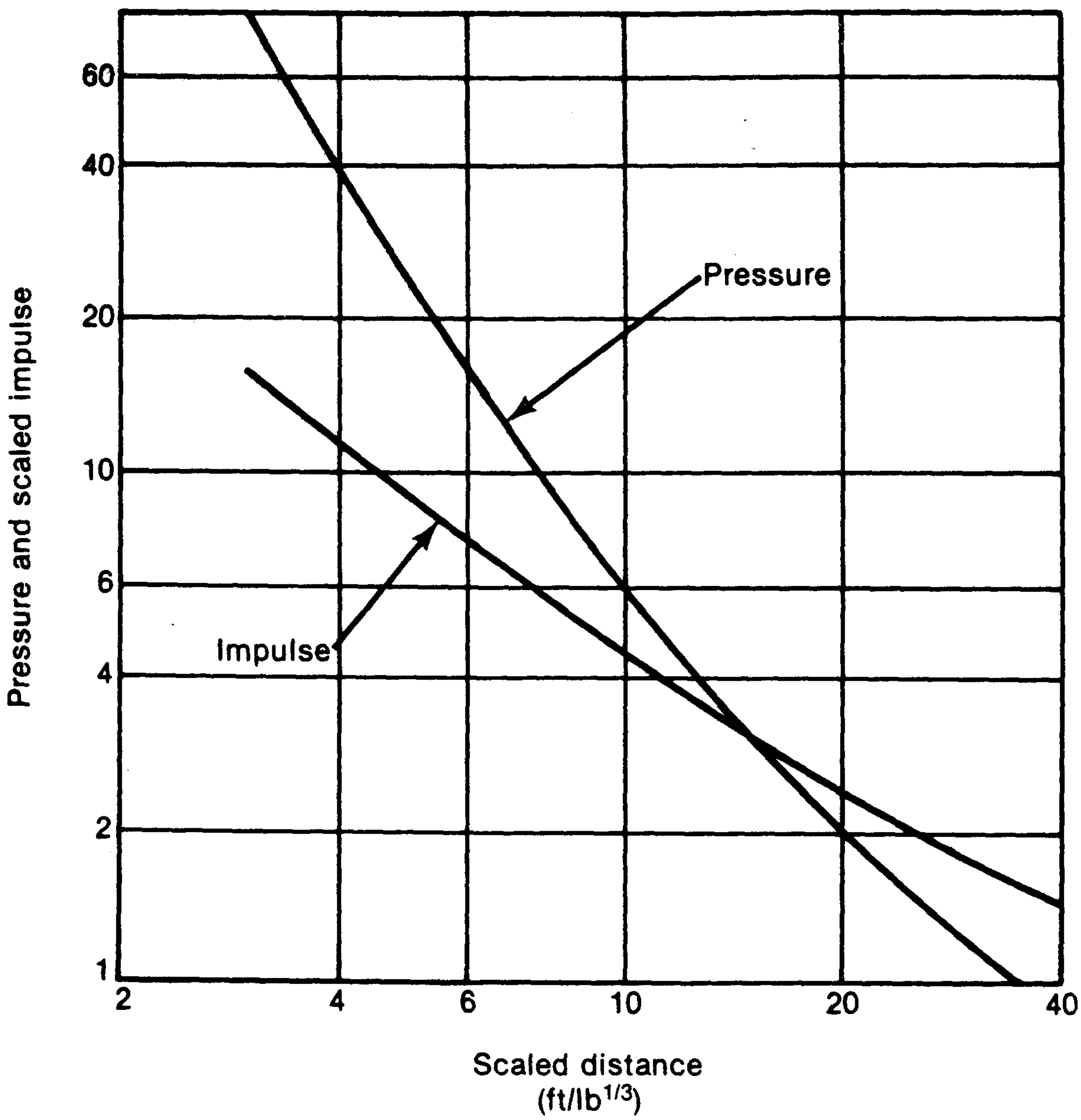


Figure 108. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for Combined Values of Single-perforated M1 Propellant.

Table 62. **Summary of Results for Hemispherical Surface Burst, Peak Pressure, and Scaled Positive Impulse for Combined Values of Multiperforated M1 Propellant.**

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	85.91	592.37	16.87	151.43	22.000	8.727	1.78	12.30	2.26	20.29
4.000	1.587	41.86	288.60	12.11	108.64	23.000	9.124	1.68	11.58	2.18	19.58
5.000	1.983	25.01	172.42	9.43	34.64	24.000	9.521	1.59	10.95	2.11	18.94
6.000	2.380	15.72	108.37	7.47	69.42	25.000	9.917	1.51	10.38	2.04	18.35
7.000	2.777	12.25	84.49	6.57	58.96	26.000	10.314	1.43	9.87	1.98	17.81
8.000	3.174	9.42	64.92	5.72	51.36	27.000	10.711	1.37	9.42	1.93	17.38
9.000	3.570	7.53	51.92	5.08	45.59	28.000	11.108	1.31	9.01	1.88	16.84
10.000	3.967	6.21	42.80	4.58	41.08	29.000	11.504	1.25	8.63	1.83	16.41
11.000	4.364	5.24	36.14	4.17	37.45	30.000	11.901	1.20	8.29	1.78	16.01
12.000	4.760	4.51	31.10	3.84	34.48	31.000	12.298	1.16	7.98	1.74	15.64
13.000	5.157	3.94	27.19	3.57	32.00	32.000	12.694	1.12	7.70	1.70	15.29
14.000	5.554	3.49	24.09	3.33	29.89	33.000	13.091	1.08	7.43	1.67	14.96
15.000	5.950	3.13	21.58	3.13	28.09	34.000	13.488	1.04	7.19	1.63	14.65
16.000	6.347	2.83	19.52	2.96	26.53	35.000	13.884	1.01	6.97	1.60	14.37
17.000	6.744	2.58	17.79	2.80	25.16	36.000	14.281	0.98	6.76	1.57	14.09
18.000	7.141	2.37	16.34	2.67	23.96	37.000	14.678	0.95	6.57	1.54	13.84
19.000	7.537	2.19	15.10	2.55	22.89	38.000	15.075	0.93	6.39	1.51	13.59
20.000	7.934	2.04	14.03	2.44	21.93	39.000	15.471	0.90	6.22	1.49	13.36
21.000	8.331	1.90	13.11	2.35	21.07	40.000	15.868	0.88	6.07	1.47	13.15



Figrue 109. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for the Combined Results of Multiperforated M1 Propellant.

M6 PROPELLANT[30]

OBJECTIVE

The objective of this program was to experimentally determine the maximum airblast output in terms of peak pressure and scaled positive impulse of multiperforated M6 propellant and compare the measured values to known characteristics of hemispherical TNT surface bursts and determine the TNT equivalency.

MATERIALS

The material was M6 multiperforated propellant for a 75 mm gun. Web size was 0.94 mm (0.037 inch). It was manufactured by Hercules Inc., Lot No. RAD-R-8-60449-V3-18320.

TEST SETUP

M6 multiperforated propellant was tested in three different configurations representative of two in-process and one shipping drum configuration. The two in-process configurations represented a closed and open hopper in 22.7 kg (50 lb) quantities. The cylindrical shipping drum contained 26.1 kg (57.5 lb) quantities.

INSTRUMENTATION

The IITRI instrumentation system is used described in the chapter entitled "INSTRUMENTATION". Twelve pressure transducers were flush mounted in two concrete runways in a 90-degree array. The scaled distances were held constant throughout the experiment.

RESULTS

The results of the shipping drum are given in Table 63 and Figure 110. The results of the closed hopper tests are given in Table 64 and Figure 111. The results of the open hopper tests are given in Table 65 and Figure 112. Individual test results are given in the orginal test report.

DISCUSSION

The pressure values for the shipping drum were less than expected at all scaled distances of the experiment. The pressure values were 750, 363, 174, 54, 14.8, and 6.07 kPa (108.71, 52.68, 25.25, 7.87, 2.14, and 0.88 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14 and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 0.8, 0.7, 0.7, 0.4, 0.4, and 0.7 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were less than expected at all scaled distances of the experiment. The scaled positive impulse values were 173, 112, 76, 45, 24.7, and 12.59 $kPa\text{-}ms/kg^{1/3}$ (19.30, 12.51, 8.50, 4.97, 2.75 and 1.40, $psi\text{-}ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and

40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.9, 0.7, 0.6, 0.5, 0.5, and 0.6 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the closed hopper tests were less than expected at all scaled distances of the experiment. The pressure values were 362, 208, 111, 40.4, 14, and 5.29 kPa (52.55, 30.22, 16.15, 5.86, 2.04, and 0.77 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 0.3, 0.3, 0.3, 0.2, 0.3, and 0.4 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values for the closed hopper tests were less than expected at all scaled distances of the experiment. The scaled positive impulse values were 96, 79, 61, 38, 20, and 11.4 kPa-ms/kg$^{1/3}$ (10.73, 8.75, 6.81, 4.22, 2.21, and 1.27 psi-ms/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.4, 0.4, 0.4, 0.4, 0.4, and 0.5 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the open hopper tests were less than expected at all scaled distances of the experiment. The pressure values were 324, 193, 110, 41.5, 12.5, and 4.79 kPa (46.99, 28.00, 15.91, 6.02, 1.81, and 0.69 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These values equate to 0.3, 0.3, 0.3, 0.3, 0.3, and 0.3 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were less than expected at all scaled distances of the experiment. The scaled positive impulse values were 90, 71, 55, 37, 22, and 11.4 kPa-ms/kg$^{1/3}$ (10.02, 7.87, 6.16, 4.13, 2.41, and 1.27 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.4, 0.3, 0.4, 0.3 ,0.4, and 0.5 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) M6 multiperforated propellant is a detonable material.

(2) The blast output from M6 propellant is dependant upon the size of the charge mass and the configuration from which it detonates.

(3) The blast output from M6 propellant does not scale as a function of charge mass in quantities less than 26 kg (57.5 lb).

Table 63. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for M6 Propellant in Shipping Drums.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	108.71	746.53	19.30	173.16	22.000	8.727	1.60	11.02	2.34	21.00
4.000	1.587	52.68	363.25	12.51	112.26	23.000	9.124	1.51	10.38	2.26	20.26
5.000	1.983	30.41	209.65	9.33	83.77	24.000	9.521	1.43	9.83	2.18	19.57
6.000	2.380	19.65	135.46	7.53	67.56	25.000	9.917	1.36	9.35	2.11	18.93
7.000	2.777	13.73	94.68	6.37	57.15	26.000	10.314	1.29	8.92	2.04	18.33
8.000	3.174	10.17	70.11	5.56	49.91	27.000	10.711	1.24	8.54	1.98	17.77
9.000	3.570	7.87	54.26	4.97	44.56	28.000	11.108	1.19	8.21	1.92	17.23
10.000	3.967	6.30	43.46	4.51	40.44	29.000	11.504	1.15	7.91	1.86	16.73
11.000	4.364	5.19	35.80	4.14	37.15	30.000	11.901	1.11	7.64	1.81	16.26
12.000	4.760	4.38	30.17	3.84	34.45	31.000	12.298	1.07	7.40	1.76	15.81
13.000	5.157	3.76	25.91	3.59	32.19	32.000	12.694	1.04	7.19	1.71	15.38
14.000	5.554	3.28	22.61	3.37	30.27	33.000	13.091	1.01	7.00	1.67	14.98
15.000	5.950	2.90	20.00	3.19	28.60	34.000	13.488	0.99	6.82	1.63	14.59
16.000	6.347	2.60	17.91	3.02	27.14	35.000	13.884	0.97	6.66	1.58	14.22
17.000	6.744	2.35	16.20	2.88	25.84	36.000	14.281	0.95	6.52	1.55	13.87
18.000	7.141	2.14	14.79	2.75	24.68	37.000	14.678	0.93	6.39	1.51	13.53
19.000	7.537	1.97	13.60	2.63	23.63	38.000	15.075	0.91	6.27	1.47	13.20
20.000	7.934	1.83	12.60	2.53	22.68	39.000	15.471	0.89	6.17	1.44	12.89
21.000	8.331	1.70	11.75	2.43	21.81	40.000	15.868	0.88	6.07	1.40	12.59

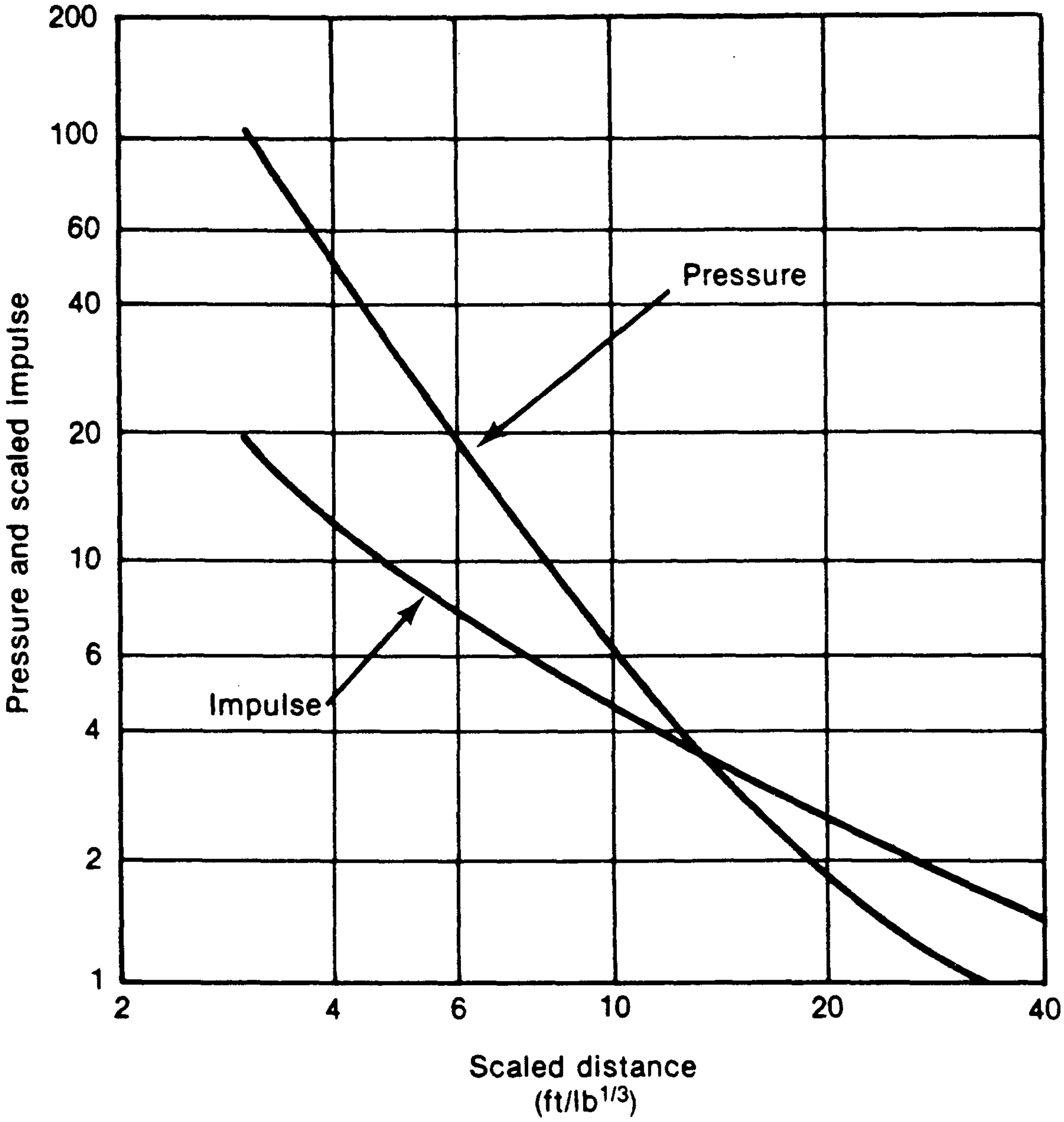


Figure 110. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for M6 Propellant in Shipping Drums.

Table 64. **Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for M6 Propellant in Closed Hopper Configuration.**

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	52.55	362.36	10.73	96.28	22.000	8.727	1.60	11.02	1.87	16.77
4.000	1.587	30.22	208.37	8.75	78.51	23.000	9.124	1.52	10.46	1.80	16.19
5.000	1.983	18.98	130.87	7.28	65.36	24.000	9.521	1.44	9.96	1.75	15.67
6.000	2.380	12.96	89.37	6.20	55.60	25.000	9.917	1.38	9.50	1.69	15.20
7.000	2.777	9.47	65.29	5.37	48.20	26.000	10.314	1.32	9.08	1.65	14.77
8.000	3.174	7.29	50.30	4.73	42.46	27.000	10.711	1.26	8.69	1.60	14.38
9.000	3.570	5.86	40.39	4.22	37.92	28.000	11.108	1.21	8.33	1.56	14.02
10.000	3.967	4.86	33.51	3.82	34.25	29.000	11.504	1.16	7.99	1.53	13.69
11.000	4.364	4.14	28.53	3.48	31.25	30.000	11.901	1.11	7.68	1.49	13.39
12.000	4.760	3.60	24.81	3.20	28.75	31.000	12.298	1.07	7.38	1.46	13.11
13.000	5.157	3.18	21.95	2.97	26.65	32.000	12.694	1.03	7.10	1.43	12.86
14.000	5.554	2.86	19.69	2.77	24.87	33.000	13.091	0.99	6.84	1.41	12.62
15.000	5.950	2.59	17.86	2.60	23.33	34.000	13.488	0.96	6.59	1.38	12.40
16.000	6.347	2.37	16.36	2.45	22.00	35.000	13.884	0.92	6.35	1.36	12.20
17.000	6.744	2.19	15.11	2.32	20.84	36.000	14.281	0.89	6.12	1.34	12.02
18.000	7.141	2.04	14.05	2.21	19.82	37.00	14.678	0.86	5.90	1.32	11.88
19.000	7.537	1.91	13.14	2.11	18.92	38.000	15.075	0.82	5.69	1.30	11.68
20.00	7.934	1.79	12.34	2.02	18.12	39.000	15.471	0.80	5.48	1.29	11.54
21.000	8.331	1.69	11.64	1.94	17.41	40.000	15.868	0.77	5.29	1.27	11.40

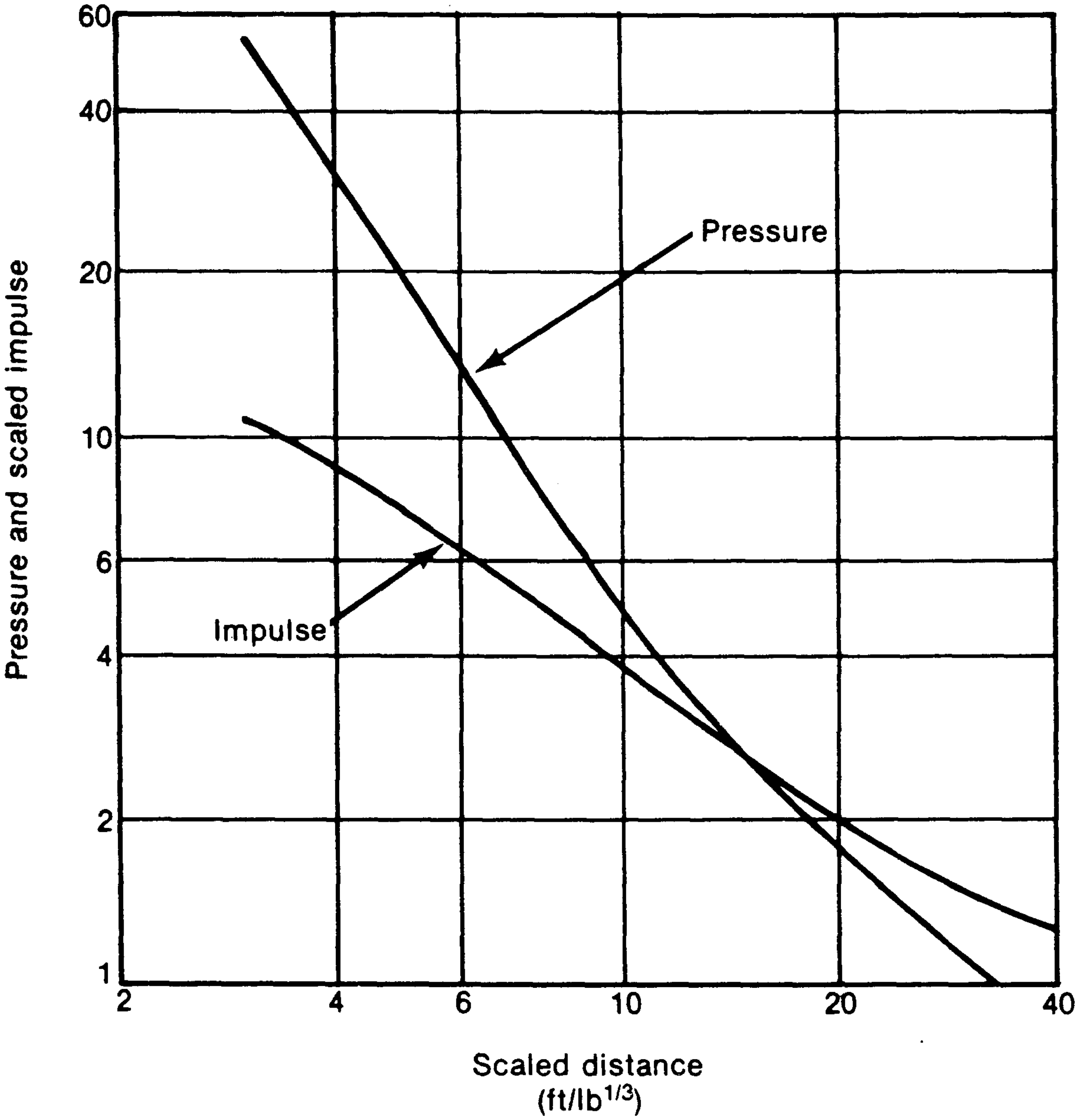


Figure 111. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for M6 Propellant in Closed Hopper Configuration.

Table 65. **Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for M6 Propellant in Open Hopper Configuration.**

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	46.99	323.99	10.02	89.91	22.000	8.727	1.35	9.29	2.06	18.51
4.000	1.587	28.00	193.05	7.87	70.59	23.000	9.124	1.27	8.74	1.99	17.75
5.000	1.983	18.42	126.99	6.56	58.75	24.000	9.521	1.20	8.25	1.93	17.28
6.000	2.380	13.01	89.68	5.67	50.87	25.000	9.917	1.13	7.82	1.86	16.73
7.000	2.777	9.69	66.78	5.02	45.04	26.000	10.314	1.08	7.45	1.81	16.21
8.000	3.174	7.51	51.80	4.52	40.58	27.000	10.711	1.03	7.11	1.75	15.73
9.000	3.570	6.02	41.50	4.13	37.03	28.000	11.108	0.99	6.81	1.70	15.28
10.000	3.967	4.95	34.13	3.80	34.12	29.000	11.504	0.95	6.53	1.66	14.86
11.000	4.364	4.16	28.68	3.53	31.70	30.000	11.901	0.91	6.29	1.61	14.46
12.000	4.760	3.56	24.54	3.30	29.64	31.000	12.298	0.88	6.07	1.57	14.08
13.000	5.157	3.09	21.33	3.11	27.87	32.000	12.694	0.85	5.87	1.53	13.72
14.000	5.554	2.72	18.78	2.93	26.32	33.000	13.091	0.82	5.69	1.49	13.38
15.000	5.950	2.43	16.72	2.78	24.95	34.000	13.488	0.80	5.52	1.45	13.06
16.000	6.347	2.18	15.04	2.64	23.73	35.000	13.884	0.78	5.37	1.42	12.75
17.000	6.744	1.98	13.65	2.52	22.64	36.000	14.281	0.76	5.23	1.39	12.46
18.000	7.141	1.81	12.48	2.41	21.66	37.000	14.678	0.74	5.11	1.36	12.18
19.000	7.537	1.67	11.49	2.31	20.76	38.000	15.075	0.72	4.99	1.33	11.91
20.000	7.934	1.54	10.64	2.22	19.95	39.000	15.471	0.71	4.88	1.30	11.61
21.000	8.331	1.44	9.92	2.14	19.20	40.000	15.868	0.69	4.79	1.27	11.42

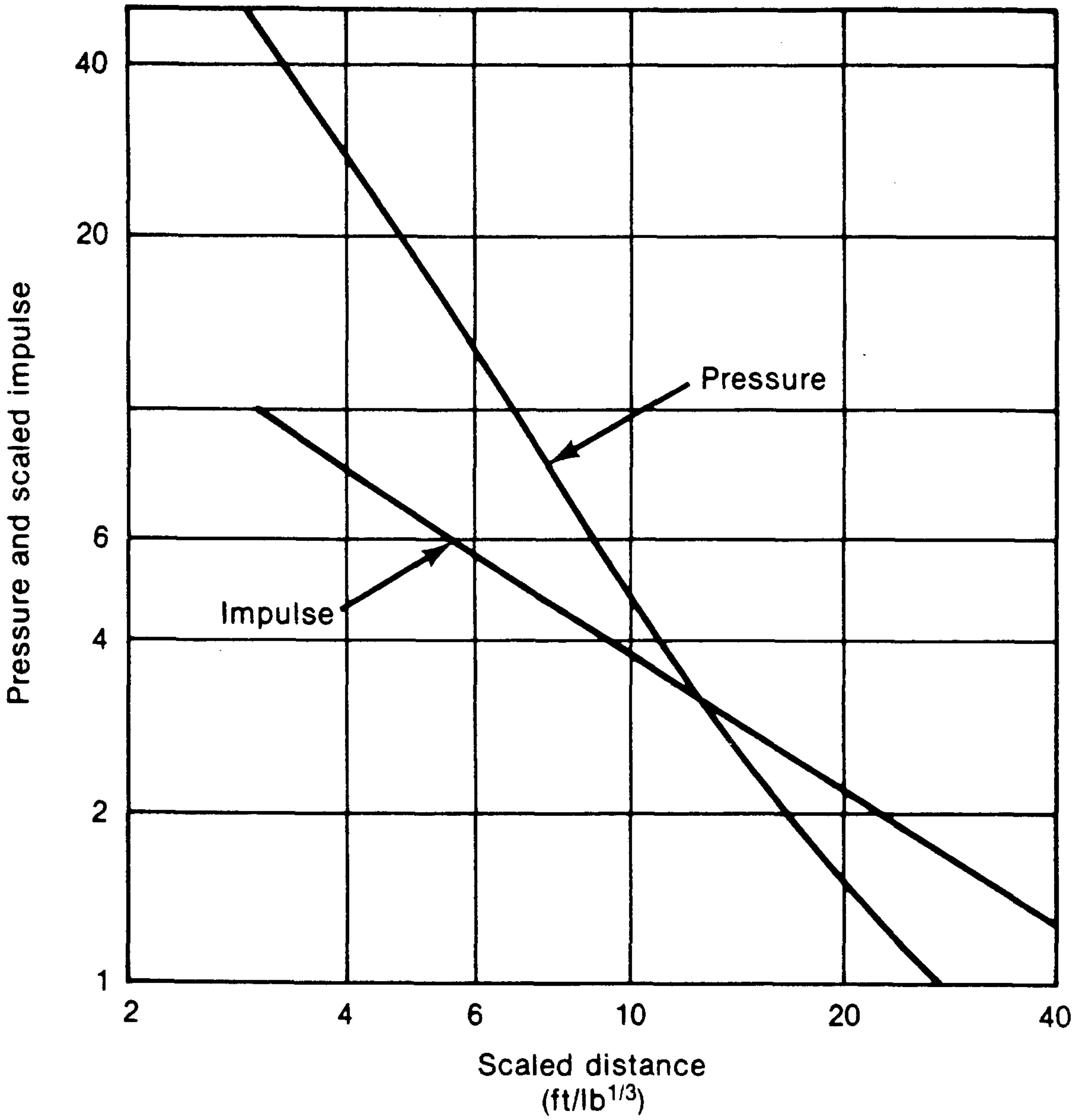


Figure 112. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for M6 Propellant in Open Hopper Configuration.

OBJECTIVE

The objective of this study was to determine the maximum output from the detonation of M10 Propellant in terms of airblast overpressure and positive impulse. The measured values were compared with known characteristics of hemispherical TNT surface burst data in order to determine TNT equivalency.

MATERIALS

The test material was Propellant, Explosive, Solid Class B propellant M10 Type 2 (Lot No. RAD 68725 and RAD 88725) 0.018 inch web nominal single perforation (SP) grain containing 98% nitrocellulose (13.5% N), 1% potassium sulfate and 1% dipheylamine.

TEST SETUP

Airblast output was evaluated for masses and configurations of M10 propellant representative of three shipping and in-plant situations. Physical characteristics of the test items are as follows:

(1) An orthorhombic container used to simulate the conveyor bucket consisted of a two-piece telescoping fiberboard box filled with 11.34 kg (25 lb) of propellant.

(2) M-17 and M-24 orthorhombic metal lined wooden boxes filled with 22.7, 45.5, and 65.8 kg (50, 100, and 145 lb) of propellant.

(3) M-25 an orthorhombic stainless steel vented container filled with 45.4 kg (100 lb) of propellant.

INSTRUMENTATION

Twelve side-on pressure transducers were flush mounted to the ground surface in two sand-filled runways in a 90-degree array. The scaled distances ranged from 1.19 to 15.87 $m/kg^{1/3}$ (3.0 to 40.0 $ft/lb^{1/3}$) and held constant throughout the experiments.

RESULTS

The combined results of the orthorhombic configuration with charge weights of 11.34, 22.7, and 45.4 kg (25, 50 and 100 lb) with a length to diameter ratio of 1.8:1 are given in Table 66 and Figure 113. The results of the 65.77 kg (145 lb) charge weight and a L/D ratio =0.5:1 are shown in Table 67 and Figure 114. Results of individual test results are given in the orginal test report.

DISCUSSION

Peak pressure values for the combined charge weights with a L/D ratio of 1.8:1 were greater than expected at scaled distances equal to or less than 2.14 $m/kg^{1/3}$ (5.4 $ft/lb^{1/3}$) and less than expected at scaled distances equal to or greater than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$). The pressure values were 1127, 613, 285, 76, 19, and 7.08 kPa (163.50, 88.95, 41.27, 10.92, 2.72, and 1.03 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 1.4, 1.4, 1.4, 0.9, 0.6, and 0.7 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were greater than expected at scaled distances equal to or less than 2.14 $m/kg^{1/3}$ (5.4 $ft/lb^{1/3}$) and less than expected at scaled distances equal to or greater than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$). The scaled positive impulse values were 498, 304, 156, 58, 33, and 15 kPa-ms/$kg^{1/3}$ (55.48, 33.88, 17.38, 6.44, 3.66, and 1.67 psi-ms/$lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 5.8, 3.8, 1.9, 0.7, 0.8, and 0.8 times equal amounts of TNT at the same scaled distances, respectively. The high impulse values at the near-field distances less than 2.14 $m/kg^{1/3}$ (5.4 $ft/lb^{1/3}$ are attributable in part to the propellant burning reaction.

The pressure values for the 65.8 kg (145 lb) charge weight in an orthorhombic container were greater than expected at scaled distances equal to or less than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$) and less than expected at scaled distances equal to or greater than 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$). The peak pressure values were 940, 556, 282, 82, 21, and 9.25 kPa (136.37, 80.66, 40.83, 11.90, 3.01, and 1.34 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 1.0, 1.2, 1.2, 1.1, 0.7, and 1.3 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values for the 65.8 kg (145 lb) charge weight in an orthorhombic configuration were greater than expected at equal to or less than 2.14 $m/kg^{1/3}$ (5.4 $ft/lb^{1/3}$) and less than expected at scaled distances equal to or greater than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$). The scaled positive impulse values were 344, 332, 180, 54, 31, and 11.52 kPa-ms/$kg^{1/3}$ (38.36, 37.04, 20.09, 6.00, 3.41 and 1.28 psi-ms/$lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0 and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 3.1, 5.2, 2.0, 0.9, 0.7, and 0.5 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) TNT equivalency were determined for M10 propellant in four in-process manufacturing configurations.

(2) The pressure and impulse values were greater than expected at the near-field scaled distances (Z equql to or less than 3 $m/kg^{1/3}$) and less than expected at scaled distances greater than 3 $m/kg^{1/3}$.

(3) The blast output from the detonation of M10 propellant is dependent upon the configuration tested.

(4) To within experimental limits, M10 scaled as a cube root function of the charge weight.

Table 66. Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for M10 Propellant in Orthorhombic Configuration, L/D=1.8:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	157.73	1087.52	56.21	504.58	22.000	8.727	2.08	14.31	3.29	29.54
4.000	1.587	92.09	634.94	32.54	292.02	23.000	9.124	1.97	13.59	3.22	28.88
5.000	1.983	52.76	363.80	19.95	179.07	24.000	9.521	1.88	12.96	3.14	28.21
6.000	2.340	32.15	221.69	13.49	121.06	25.000	9.917	1.80	12.40	3.07	27.51
7.000	2.777	21.05	145.12	9.95	89.27	26.000	10.314	1.72	11.89	2.99	26.79
8.000	3.174	14.70	101.36	7.86	70.54	27.000	10.711	1.66	11.44	2.90	26.05
9.000	3.570	10.85	74.80	6.55	58.81	28.000	11.108	1.60	11.03	2.82	25.28
10.000	3.967	8.38	57.77	5.69	51.08	29.000	11.504	1.54	10.65	2.73	24.48
11.000	4.364	6.72	46.34	5.10	45.77	30.000	11.901	1.49	10.30	2.64	23.65
12.000	4.760	5.56	38.34	4.68	42.00	31.000	12.298	1.45	9.98	2.54	22.81
13.000	5.157	4.72	32.56	4.37	39.25	32.000	12.694	1.40	9.67	2.44	21.94
14.000	5.554	4.10	28.24	4.14	37.18	33.000	13,091	1.36	9.38	2.35	21.06
15.000	5.950	3.62	24.95	3.96	35.58	34.000	13.488	1.32	9.11	2.25	20.16
16.000	6.347	3.24	22.37	3.82	34.31	35.000	13.884	1.28	8.85	2.15	19.27
17.000	6.744	2.95	20.31	3.71	33.27	36.000	14.281	1.25	8.60	2.05	18.36
18.000	7.141	2.70	18.65	3.61	32.38	37.000	14.678	1.21	8.36	1.95	17.46
19.000	7.537	2.50	17.27	3.52	31.60	38.000	15.075	1.18	8.13	1.85	16.57
20.000	7.934	2.34	16.12	3.44	30.89	39.000	15,471	1.15	7.91	1.75	15.69
21.000	8.331	2.20	15.15	3.37	30.21	40.000	15.868	1.12	7.69	1.65	14.82

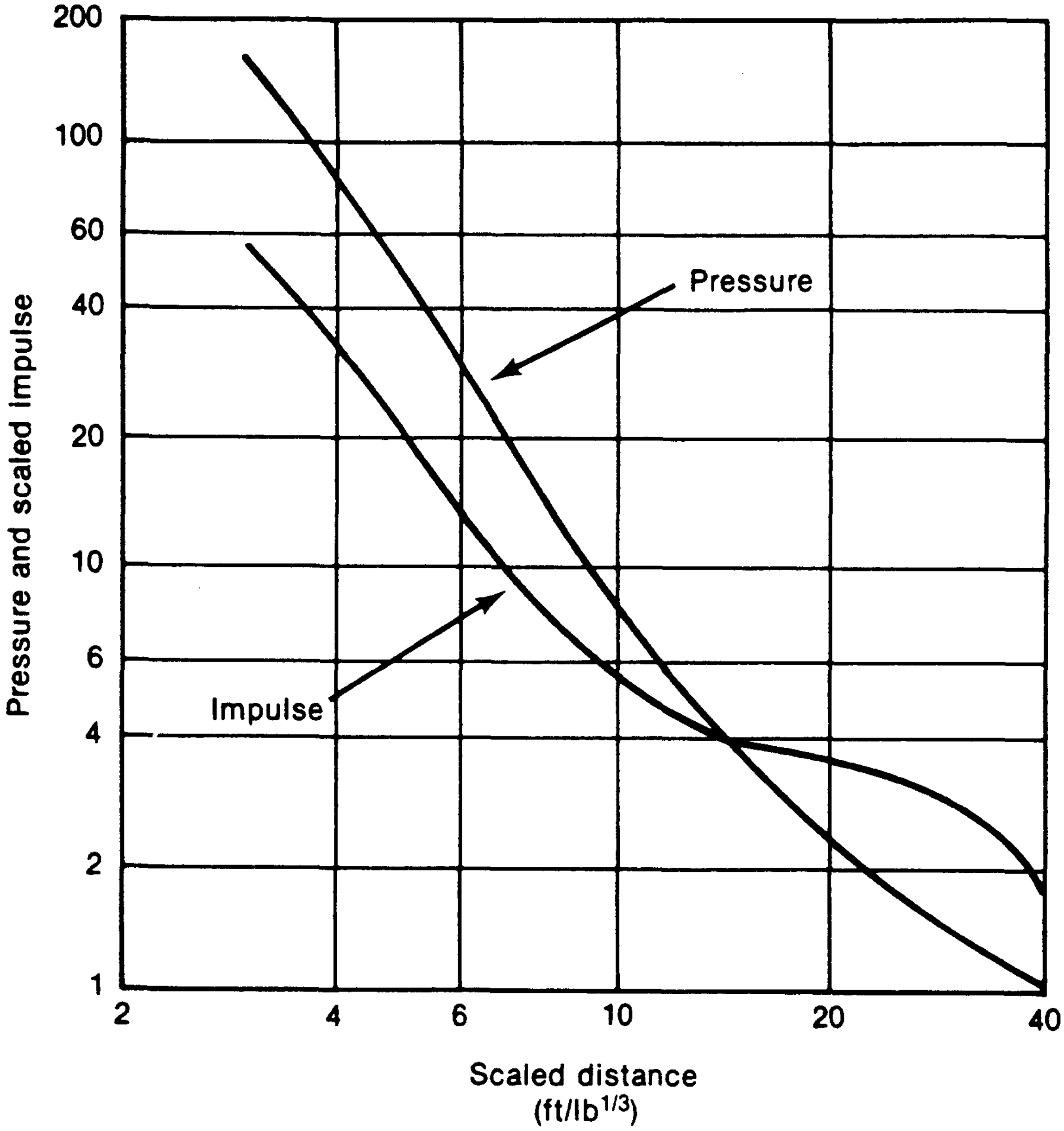


Figure 113. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for M10 Propellant in an Orthorhombic Configuration, L/D=1.8:1.

Table 67. Summary of Results of Hemispherical Surface Bursts, Peak Pressure and Scaled Positive Impulse for M10 Propellant in an Orthorhombic Configuration, L/D=0.6:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	136.37	940.26	38.36	344.22	22.000	8.727	2.27	15.65	3.39	30.43
4.000	1.587	80.66	556.16	37.04	332.36.	23.000	9.124	2.15	14.82	3.37	30.23
5.000	1.983	49.01	337.89	24.19	217.09	24.000	9.521	2.04	14.09	3.33	29.91
6.000	2.380	31.65	218.25	15.38	138.02	25.000	9.917	1.95	13.46	3.28	29.46
7.000	2.777	21.73	149.80	10.42	93.47	26.000	10.314	1.87	12.91	3.22	28.86
8.000	3.174	15.72	108.41	7.63	68.45	27.000	10.711	1.80	12.43	3.31	28.13
9.000	3.570	11.90	82.04	6.00	53.87	28.000	11.103	1.74	12.00	3.04	27.25
10.000	3.967	9.35	64.44	5.02	45.01	29.000	11.504	1.69	11.62	2.92	26.24
11.000	4.364	7.57	52.22	4.40	39.46	30.000	11.901	1.64	11.28	2.80	25.12
12.000	4.760	6.30	43.44	4.00	35.93	31.000	12.298	1.59	10.98	2.66	23.90
13.000	5.157	5.36	36.94	3.75	33.67	32.000	12.694	1.55	10.70	2.52	22.59
14.000	5.554	4.64	32.01	3.59	32.25	33.000	13.091	1.52	10.46	2.36	21.22
15.000	5.950	4.09	28.19	3.50	31.39	34.000	13.488	1.48	10.23	2.21	19.81
16.000	6.347	3.65	25.17	3.44	30.91	35.000	13.884	1.45	10.03	2.05	18.38
17.000	6.744	3.30	22.75	3.42	20.67	36.000	14.281	1.43	9.85	1.89	16.99
18.000	7.141	3.01	20.77	3.41	30.58	37.000	14.678	1.40	9.68	1.73	15.52
19.000	7.537	2.78	19.14	3.41	30.56	38.000	15.075	1.38	9.52	1.58	14.14
20.000	7.934	2.58	17.78	3.41	30.56	39.000	15.471	1.36	9.38	1.43	12.80
21.000	8.331	2.41	16.63	3.40	30.53	40.000	15.868	1.34	9.25	1.28	11.52

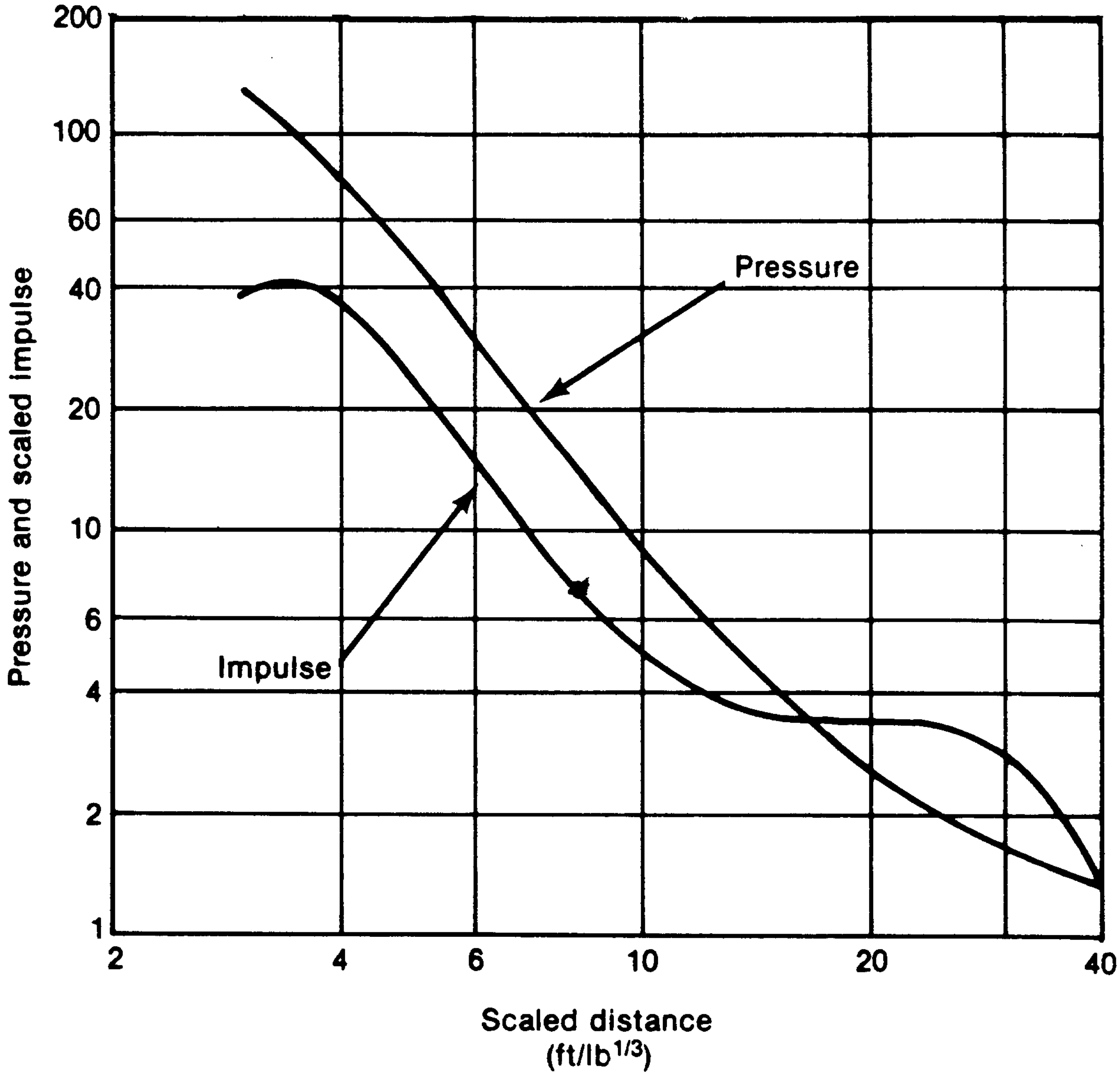


Figure 114. Peak Pessure and Scaled Positive Impulse Versus Scaled Distance for M10 Propellant in an Orthorhombic Configuration. L/D=0.6:1.

OBJECTIVE

The objective of this study was to determine the maximum airblast output from the detonation of M26E1 multiperforated propellant in terms of peak overpressure and positive impulse. The measured values were compared to known characteristics of hemispherical TNT surface burst data to determine TNT equivalency.

MATERIALS

M26E1 propellant is a multiperforated propellant with a grain approximately 5.08 mm (0.200 inch) in diameter by 9.53 mm (0.38 inch) long.

TEST SETUP

M26E1 propellant were tested in cylindrical and orthorhombic configurations. The physical characteristics were as follows:

(1) Cylindrical fiberboard shipping containers in subscale and full scale configurations with a L/D ratio of 1.6:1.

(2) Orthorhombic dryer bed configurations constructed from plywood were tested in both subscale and full-scale configurations.

(3) Orthorhombic configuration representing a drop buggy constructed from plywood was filled with 408 kg (900 lb) of propellant.

(4) Cylindrical container constructed from stainless steel was used as a blender barrel.

INSTRUMENTATION

The instrumentation used in these experiments is described in the chapter entitled "INSTRUMENTATION", shown in Figure 36.

RESULTS

Test results of the individual tests are given in the orginal test report. The results of the different configurations were combined for statistical validity. The data represented here is one standard deviation of the mean of the combined results. The results of the cylindrical blender configuration are given in Table 68 and Figure 115. The results of the dryer bed tests are given in Table 69 and Figure 116. The results of drop buggy tests are given in Table 70 and Figure 117. The cylindrical container results are given in Table 71 and Figure 118.

DISCUSSION

The peak pressure values for the blender configuration were less than equal amounts of TNT at all scaled distances of the experiment. The pressure values were less than expected at scaled distances equal to or less than 2.14 m/kg$^{1/3}$ (5.4 ft/lb$^{1/3}$) and greater than expected at a scaled distance of 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$) and less than expected at scaled distances equal to or greater than 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$). The pressure values for the multiperforated propellant in the blender barrel configuration were 750, 427, 238, 88, 23, and 7.78 kPa (108.77, 62.03, 34.53, 12.74, 3.28, and 0.69 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 0.8, 0.8, 1.0, 1.1, 0.9, and 0.3 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were less than expected at all scaled distances of the experiment. The scaled positive impulse values were 155, 119, 90, 56, 29, and 13.79 kPa-ms/kg$^{1/3}$ (17.32, 13.23, 10.00, 6.20, 3.24, and 1.54 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.9, 0.8, 0.8, 0.7, 0.,7 and 0.7 times equal amounts of TNT at the same scaled distances, respectively.

Peak pressure values for the multiperforated M26E1 propellant in the dryer bed configuration were greater than expected at scaled distances equal to or less than 1.59 m/kg$^{1/3}$ (4.0 ft/lb$^{1/3}$), less than expected at scaled distances between 2.14 to 7.14 m/kg$^{1/3}$ (5.4 and 18.0 ft/lb$^{1/3}$) and equal to the expected value at a scaled distance of 15.87 m/kg$^{1/3}$ (40.0 ft/lb$^{1/3}$). The pressure values were 1033, 471, 222, 72, 21, and 8.22 kPA (149.85, 68.27, 32.13, 10.41, 3.09, and 1.19 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 1.2, 1.0, 0.9, 0.8, 0.8, and 1.0 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were equal to or slightly greater than expected at all scaled distances except at 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$) where it was slightly less than expected. The scaled positive impulse values were 173, 135, 104, 67, 37, and 18.43 kPa-ms/kg$^{1/3}$ (19.29, 15.72, 11.60, 7.46, 4.10, and 2.05 psi-ms/kg$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values for the mulitperforated grain in the dryer bed configuration equate to 1.0, 1.0, 1.0, 0.9, 1.0, and 1.1 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for M26E1 propellant (MP) in the drop buggy configuration were greater than expected at scaled distances equal to or less than 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$) and less than expected at a scaled distance of 15.87 m/kg$^{1/3}$ (40.0 ft/lb$^{1/3}$). The pressure values were 1767, 935, 481, 155, 33, and 5.71 kPa (256.32, 135.57, 69.76, 22.51, 4.85, and 0.83 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 2.5, 2.5, 2.5, 2.5, 1.8, and 0.4 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were equal to or greater than expected at all scaled distances of the experiment except at a scaled distance of 15.87 m/kg$^{1/3}$ (40.0 ft/lb$^{1/3}$). The scaled positive impulse values were 243, 184, 137, 83, 42, and 19.47 kPa-ms/kg$^{1/3}$ (27.09, 20.47, 15.28, 9.28, 4.72, and 2.17 psi-ms/lb$^{1/3}$) at scaled distaces of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 1.8, 1.7, 1.6, 1.3, 1.2, and 1.2 times equal amounts of TNT at the same scaled distance, respectively.

The combined results of the M26E1 multiperforated propellant in cylindrical containers were greater than expected at scaled distances equal to or less than 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$) and less than expected at scaled distances equal to or greater than 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$). The pressure values were 1639, 682, 362, 83, 21, and 7.19 kPa (237.77, 98.93, 52.53, 12.07, 3.08, and 1.04 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 2.2, 1.6, 1.3, 1.0, 0.8, and 0.7 times equal amounts of TNT at the same scaled distances respectively. The scaled positive impulse values followed the same general trend as the pressure values. The scaled positive impulse values were greater than expected at scaled distances equal to or less than 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$) and less than expected at scaled distances equal to or greater than 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$). The scaled positive impulse values were 189, 142, 114, 64, 32, and 14.78 kPa-ms/kg$^{1/3}$ (21.02, 15.84, 12.72, 7.14, 3.61, and 1.65 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14 and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 1.3, 1.1, 1.0, 0.9, 0.8, and 0.8 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) M26E1 multiperforated propellant is a detonable material.

(2) It can generate peak pressures and positive impulse values in excess of equal amounts of TNT at the same scaled distances.

(3) The blast output is dependent upon the configuration from which it detonates.

(4) The blast output from M26E1 propellant scales as a cube root function of the charge weights when detonated in quantities greater than 25 kg (65 lb).

Table 68. **Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for M26E1 Multiperforated Propellant in Cylindrical Blender Barrel Configuration, L/D=1.1:1.**

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	109.03	751.75	17.32	155.42	22.000	8.727	2.21	15.26	2.69	24.12
4.000	1.587	61.11	428.26	13.23	118.77	23.000	9.124	2.03	13.99	2.58	23.14
5.000	1.983	40.15	276.80	10.74	96.40	24.000	9.521	1.87	12.88	2.48	22.24
6.000	2.380	28.10	193.78	9.06	81.29	25.000	9.917	1.72	11.89	2.39	21.40
7.000	2.777	20.79	143.34	7.84	70.38	26.000	10.314	1.60	11.01	2.30	20.63
8.000	3.174	16.01	110.39	6.92	62.12	27.000	10.711	1.48	10.23	2.22	19.92
9.000	3.570	12.72	87.68	6.20	55.64	28.000	11.108	1.38	9.52	2.15	19.25
10.000	3.967	10.35	71.35	5.62	50.42	29.000	11.504	1.29	8.89	2.08	18.63
11.000	4.364	8.59	59.22	5.14	46.12	30.000	11.901	1.21	8.32	2.01	18.05
12.000	4.760	7.24	49.95	4.74	42.51	31.000	12.298	1.13	7.80	1.95	17.50
13.000	5.157	6.19	42.71	4.40	39.45	32.000	12.694	1.06	7.33	1.89	16.99
14.000	5.554	5.36	36.95	4.10	36.81	33.000	13.091	1.00	6.91	1.84	16.51
15.000	5.950	4.68	32.28	3.85	34.51	34.000	13.488	0.94	6.51	1.79	16.05
16.00	6.347	4.13	28.46	3.62	32.49	35.000	13.884	0.89	6.16	1.74	15.63
17.000	6.744	3.67	25.27	3.42	30.70	36.000	14.281	0.84	5.83	1.70	15.22
18.000	7.141	3.28	22.60	3.24	29.10	37.000	14.678	0.80	5.52	1.65	14.83
19.000	7.537	2.95	20.33	3.08	27.66	38.000	15.075	0.76	5.24	1.61	14.47
20.000	7.934	2.67	18.39	2.94	26.37	39.000	15.471	0.72	4.98	1.57	14.12
21.000	8.331	2.42	16.72	2.81	24.12	40.000	15.868	0.69	4.74	1.54	13.79

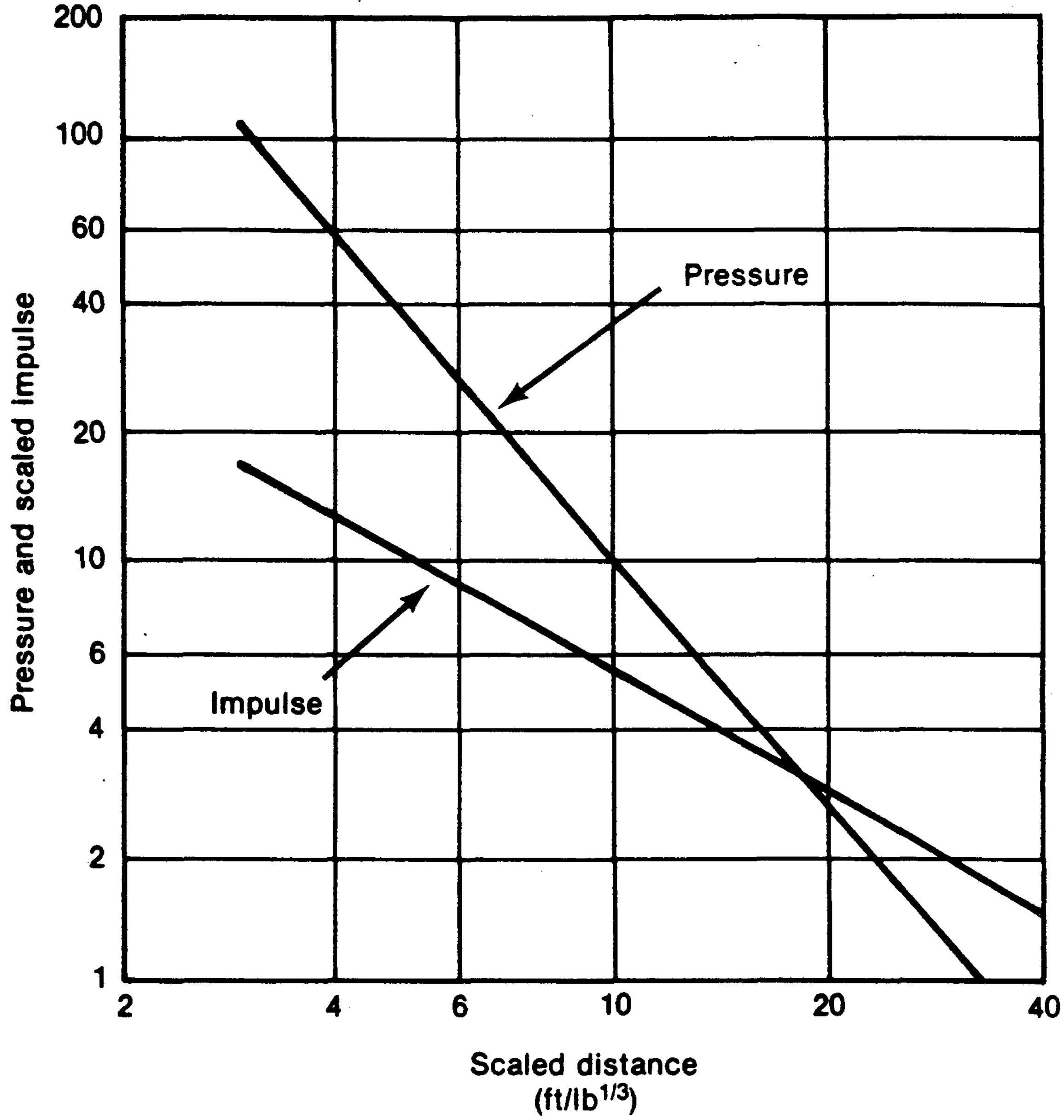


Figure 115. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for M26E1 Multiperforated Propellant in Cylindrical Blender Barrel Configuration, L/D=1.1:1.

Table 69. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for M26E1 Multiperforated Propellant in Orthorhombic Dryer Bed Configuration, L/D=0.5:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	149.85	1033.21	19.29	173.14	22.000	8.727	2.33	16.03	3.44	30.90
4.000	1.587	68.27	470.69	15.04	135.00	23.000	9.124	2.19	15.12	3.31	29.73
5.000	1.983	38.73	267.01	12.40	111.30	24.000	9.521	2.08	14.31	3.19	28.66
6.000	2.380	25.06	172.77	10.59	95.06	25.000	9.917	1.97	13.59	3.08	27.67
7.000	2.777	17.68	121.93	9.27	83.20	26.000	10.314	1.88	12.95	2.98	26.74
8.000	3.174	13.27	91.47	8.26	74.12	27.000	10.711	1.80	12.38	2.88	25.88
9.000	3.570	10.41	71.78	7.46	66.94	28.000	11.108	1.72	11.86	2.80	25.08
10.000	3.967	8.46	58.30	6.81	61.11	29.000	11.504	1.65	11.40	2.71	24.33
11.000	4.364	7.06	48.65	6.27	56.28	30.000	11.901	1.59	10.97	2.63	23.63
12.000	4.760	6.02	41.49	5.82	52.20	31.000	12.298	1.54	10.59	2.56	22.97
13.000	5.157	5.22	36.02	5.43	48.71	32.000	12.694	1.48	10.23	2.49	22.35
14.000	5.554	4.60	31.74	5.09	45.68	33.000	13.091	1.44	9.91	2.42	21.76
15.000	5.950	4.11	28.31	4.80	43.04	34.000	13.488	1.39	9.61	2.36	21.21
16.000	6.347	3.70	25.53	4.54	40.70	35.000	13.884	1.35	9.33	2.30	20.68
17.000	6.744	3.37	23.23	4.30	38.62	36.000	14.281	1.32	9.08	2.25	20.18
18.000	7.141	3.09	21.30	4.10	36.76	37.000	14.678	1.28	8.84	2.20	19.71
19.000	7.537	2.85	19.67	3.91	35.08	38.000	15.075	1.25	8.63	2.15	19.26
20.000	7.937	2.65	18.28	3.74	33.56	39.000	15.471	1.22	8.42	2.10	18.83
21.000	8.331	2.48	17.08	3.58	32.17	40.000	15.868	1.19	8.23	2.05	18.42

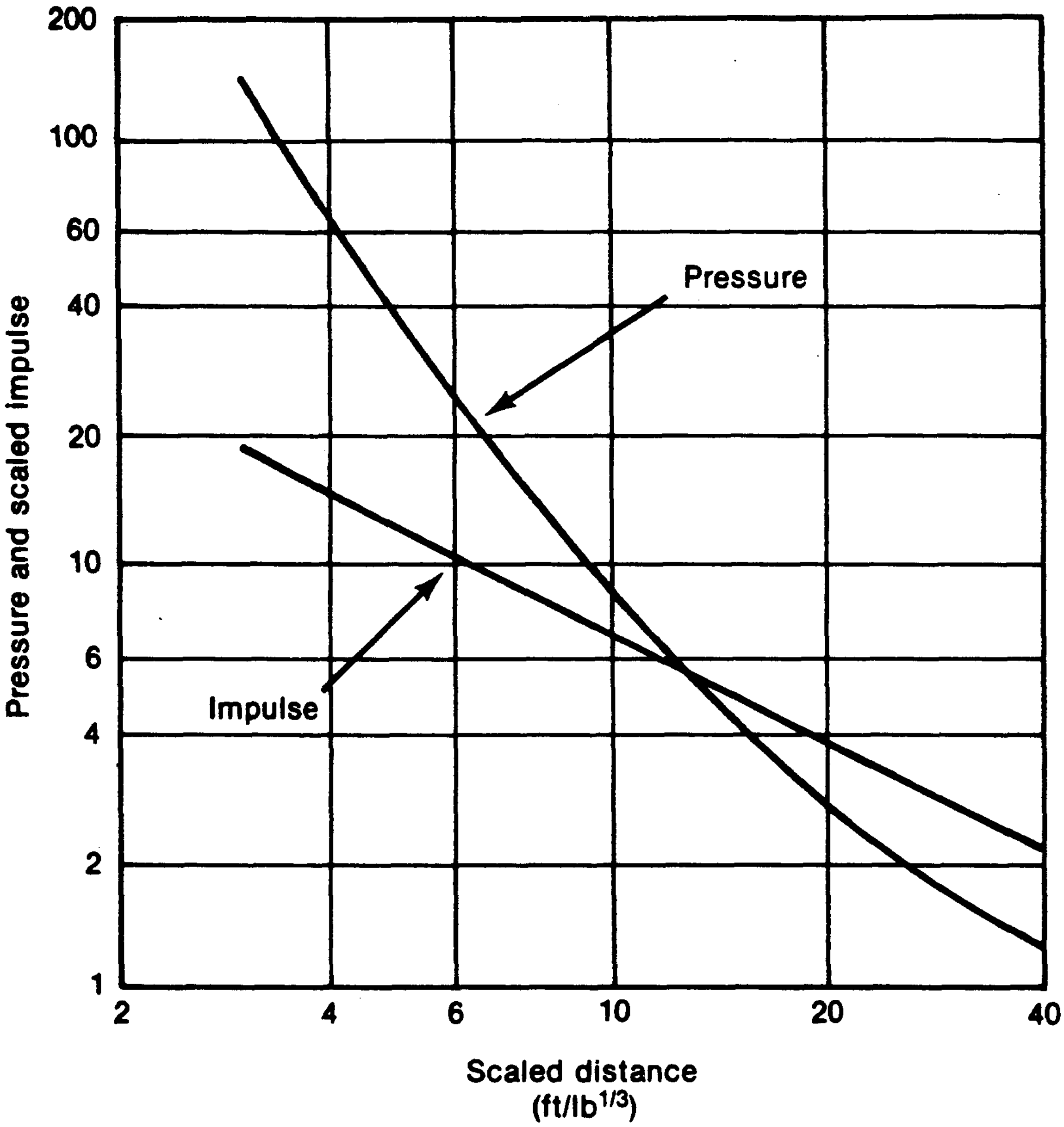


Figure 116. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for M26E1 Multiperforated Propellant in Orthorhombic Dryer Bed Configuration, L/D=0.5:1.

Table 70. Summary of Results for Hemispherical Surface Bursts, Peak Pressure and Scaled Positive Impulse for M26E1 Multiperforated Propellant in Orthorhombic Drop Buggy Configuration, L/D=1.0:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	256.32	1767.30	27.09	243.10	22.000	8.727	3.11	21.45	3.89	34.86
4.000	1.587	135.57	934.74	20.47	183.66	23.000	9.124	2.82	19.44	3.72	33.39
5.000	1.983	82.72	570.33	16.47	147.76	24.000	9.521	2.57	17.69	3.57	32.03
6.000	2.380	55.24	380.90	13.78	123.70	25.000	9.917	2.34	16.16	3.43	30.78
7.000	2.777	39.27	270.76	11.86	106.44	26.000	10.314	2.15	14.82	3.30	29.63
8.000	3.174	29.22	201.46	10.41	93.45	27.000	10.711	1.98	13.63	3.18	28.56
9.000	3.570	22.51	155.22	9.28	83.32	28.000	11.108	1.82	12.58	3.07	27.56
10.000	3.967	17.83	122.92	8.38	75.19	29.000	11.504	1.69	11.64	2.97	26.63
11.000	4.364	14.44	99.54	7.64	68.52	30.000	11.901	1.57	10.80	2.87	25.77
12.000	4.760	11.91	82.09	7.01	62.95	31.000	12.298	1.46	10.04	2.78	24.96
13.000	5.157	9.97	68.76	6.49	58.22	32.000	12.694	1.36	9.36	2.70	24.20
14.000	5.554	8.46	58.36	6.04	54.16	33.000	13.091	1.27	8.74	2.62	23.48
15.000	5.950	7.26	50.09	5.64	50.64	34.000	13.488	1.19	8.18	2.54	22.81
16.000	6.347	6.30	43.42	5.30	47.55	35.000	13.884	1.11	7.67	2.47	22.17
17.000	6.744	5.51	37.97	5.00	44.83	36.000	14.281	1.05	7.21	2.40	21.57
18.000	7.141	4.85	33.45	4.72	42.40	37.000	14.678	0.98	6.79	2.34	21.01
19.000	7.537	4.30	29.68	4.48	40.22	38.000	15.075	0.93	6.40	2.28	20.47
20.000	7.934	3.84	26.49	4.26	38.26	39.000	15.471	0.88	6.04	2.22	19.95
21.000	8.331	3.45	23.78	4.07	36.48	40.000	15.868	0.83	5.71	2.17	19.47

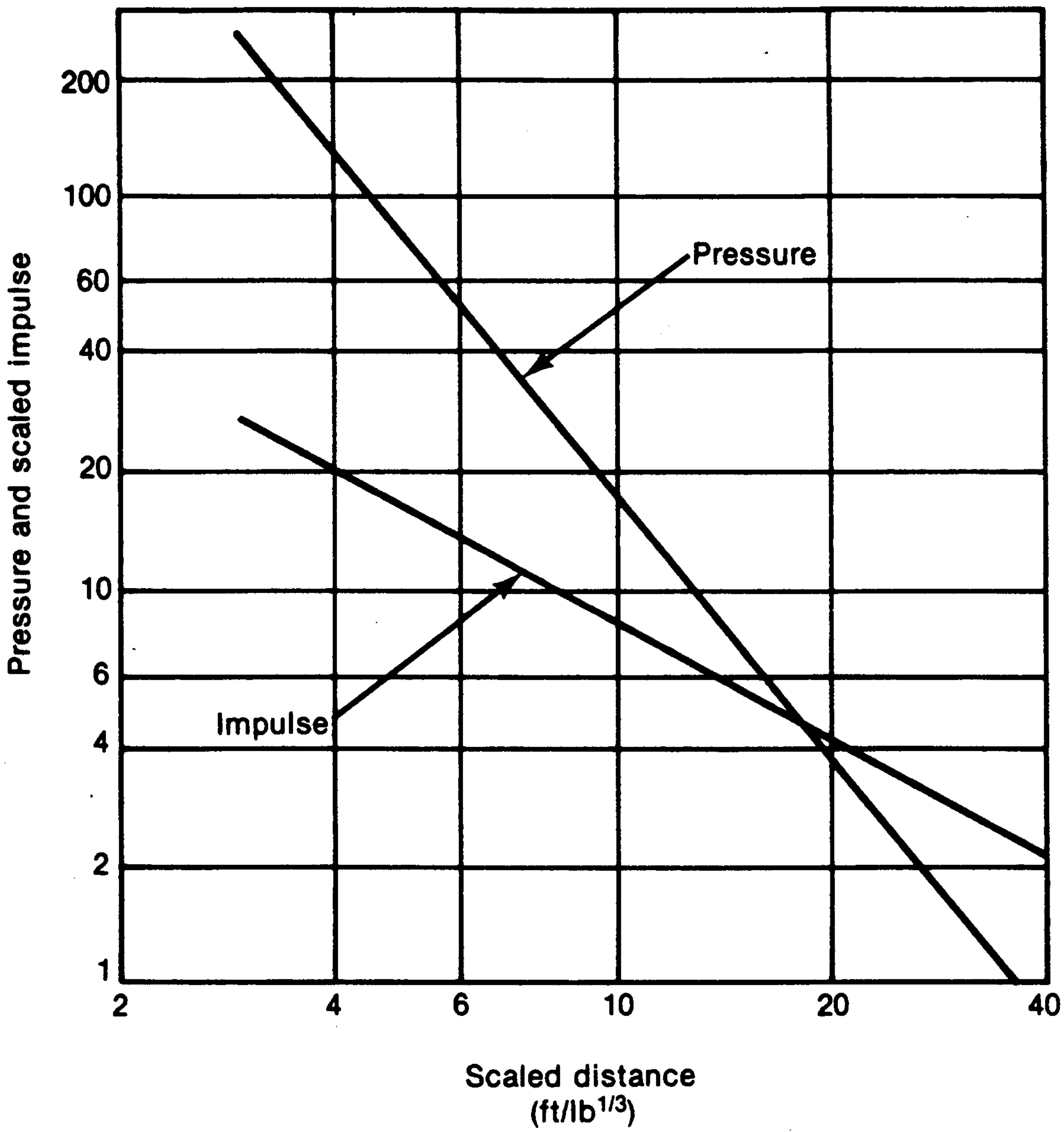


Figure 117. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for M26E1 Multiperforated Propellant in Orthorhombic Drop Buggy Configuration, L/D=1.1:1.

Table 71. Summary of Results for Hemispherical Surface Bursts, Peak Pressure and Scaled Positive Impulse for M26E1 Multiperforated Propellant in Cylindrical Configuration L/D=1.7:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	237.77	1639.40	21.02	188.60	22.000	8.727	2.23	15.39	2.96	26.60
4.000	1.587	98.93	682.14	15.84	142.14	23.000	9.124	2.09	14.39	2.84	25.46
5.000	1.983	52.53	362.21	12.72	114.14	24.000	9.521	1.96	13.52	2.72	24.42
6.000	2.380	32.29	222.65	10.63	95.41	25.000	9.917	1.85	12.76	2.61	23.46
7.000	2.777	21.86	150.74	9.14	81.99	26.000	10.314	1.75	12.08	2.51	22.57
8.000	3.174	15.84	109.25	8.01	71.90	27.000	10.711	1.66	11.47	2.42	21.75
9.000	3.570	12.07	83.25	7.14	64.04	28.000	11.108	1.58	10.93	2.34	20.98
10.000	3.967	9.56	65.92	6.43	57.74	29.000	11.504	1.51	10.44	2.26	20.27
11.000	4.364	7.80	53.80	5.86	52.58	30.000	11.901	1.45	9.99	2.18	19.61
12.000	4.760	6.52	44.99	5.38	48.27	31.000	12.298	1.39	9.59	2.12	18.98
13.000	5.157	5.56	38.37	4.97	44.61	32.000	12.694	1.34	9.23	2.05	18.40
14.000	5.554	4.83	33.27	4.62	41.48	33.000	13.091	1.29	8.89	1.99	17.85
15.000	5.950	4.24	29.26	4.32	38.76	34.000	13.488	1.25	8.59	1.93	17.34
16.000	6.347	3.78	26.03	4.05	36.38	35.000	13.884	1.20	8.31	1.88	16.85
17.000	6.744	3.39	23.40	3.82	34.27	36.000	14.281	1.17	8.05	1.83	16.39
18.000	7.141	3.08	21.22	3.61	32.40	37.000	14.678	1.13	7.81	1.78	15.95
19.000	7.537	2.81	19.40	3.42	30.72	38.000	15.075	1.10	7.59	1.73	15.54
20.000	7.934	2.59	17.85	3.25	29.21	39.000	15..471	1.07	7.38	1.69	15.15
21.000	8.331	2.40	16.53	3.10	27.84	40.000	15.868	1.04	7.19	1.65	14.78

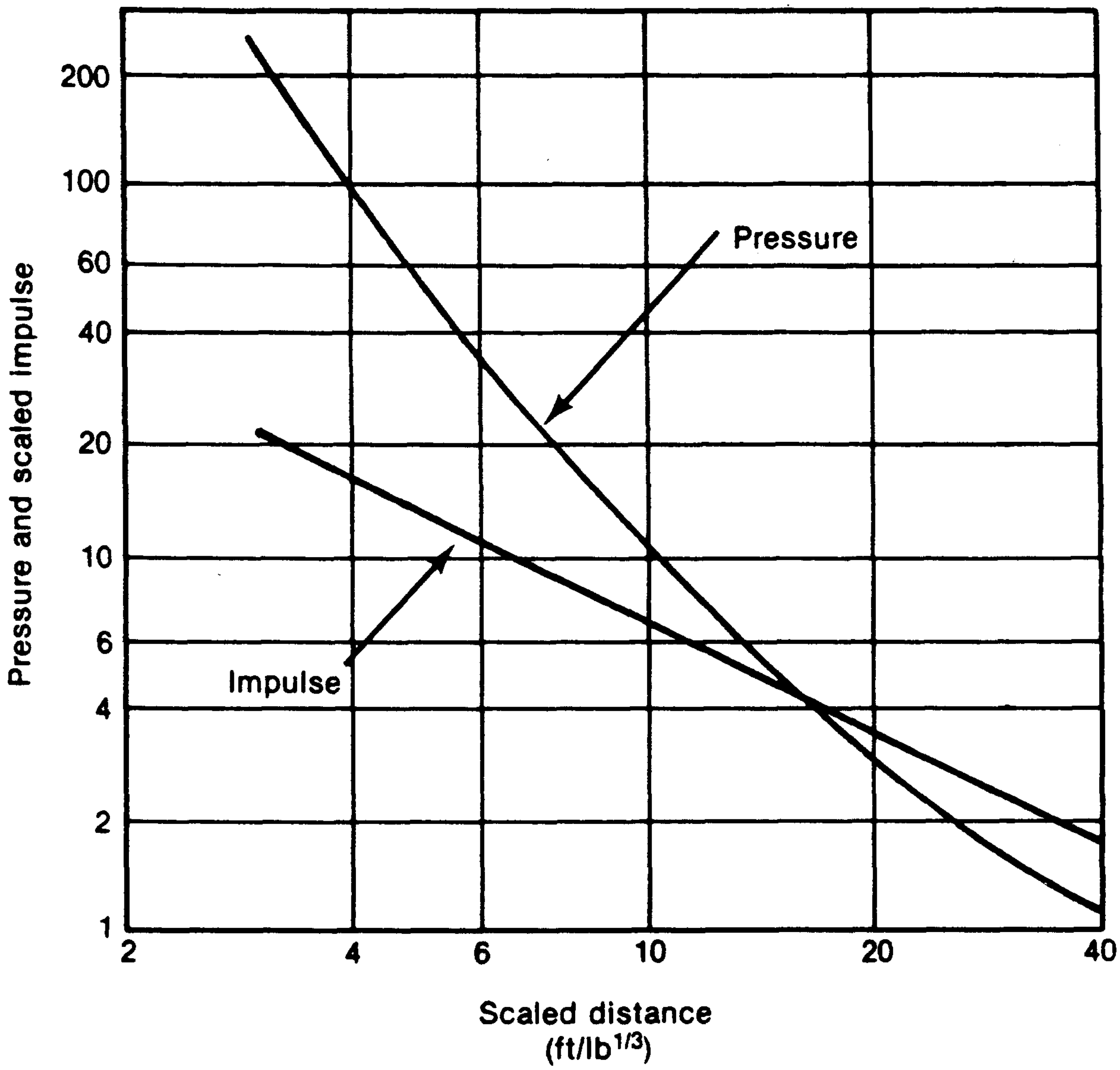


Figure 118. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for M26E1 Multiperforated Propellant in Cylindrical Configuration, L/D=1.7:1.

M30A1 PROPELLANT [33]

OBJECTIVE

The objective of this work was to experimentally determine the maximum output from the detonation of two M30A1 propellant granulations in terms of blast overpressure and positive impulse. The measured values were then compared to known characteristics of hemispherical TNT surface burst data to determine TNT equivalency.

MATERIALS

The test material was M30A1 single-perforated 0.48 mm (0.019 inch) web size and multiperforated propellant with 1.02 mm (0.040 inch) web size.

TEST SETUP

Two basic configurations were tested, cylindrical shipping drums and orthorhombic simulated dryers. Physical characteristics are as follows:

(1) Charge weights of 12.4 and 22.7 kg (30 and 50 lb) for the single-perforated and 13.5 and 26.8 kg (38 and 58 lb) multiperforated propellant were placed in a scaled fiberboard drum with a L/D ratio of 1.7:1.

(2) The simulated dryer bed was constructed from plywood and the charge weights tested were 21.2 and 22.9 kg (48 and 51 lbs). The material was tested at two different depths of 76.2 and 152.4 mm (3 and 6 inches).

INSTRUMENTATION

The IITRI instrumentation system was used. Twelve pressure transducers were mounted flush with the ground surface in steel plates in a concrete runway in a 90-degree array. However, only the pressure gages from the long side of the dryer bed were reported because the opposite gage line was lower.

RESULTS

The results of the single-perforation scaled shipping drum tests are reported in Table 72 and Figure 119. The results of the mulitperforated shipping drum tests are given in Table 73 and Figure 120. The results of the single-perforated dryer bed tests are given in Table 74 and Figure 121. The results of the multiperforated dryer bed tests are given in Table 75 and Figure 122. The original test report shows the individual test results.

DISCUSSION

The pressure values for the single perforated M30A1 propellant in the cylindrical shipping drum configuration were greater than expected at scaled distances equal to or less than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$) and less than expected at scaled distances equal to or greater than 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$). The pressure values were 1502, 641, 280, 80, 19.5, and 5.9 kPa (217.95, 92.92, 40.68, 11.57, 2.83, and 0.85 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 2.0, 1.5, 1.2, 1.0, 0.7, and 0.5 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were equal to or greater than expected at scaled distances equal to or less than 1.59 $m/kg^{1/3}$ (4.0 $ft/lb^{1/3}$) and less than expected at scaled distances equal to or greater than 2.14 $m/kg^{1/3}$ (5.4 $ft/lb^{1/3}$). The scaled positive impulse values were 210, 144, 99, 55, 28.2, and 15.7 kPa-ms/$kg^{1/3}$ (23.38, 16.07, 11.07, 6.18, 3.13, and 1.75 psi-ms/$lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 3.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 1.4, 1.1, 0.9, 0.7, 0.7, and 0.9 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the multiperforated M30A1 propellant in scaled shipping drum configuration were greater than expected at scaled distances equal to or less than 2.14 $m/kg^{1/3}$ (5.4 $ft/lb^{1/3}$) and less than expected at scaled distances equal to or greater than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$). The pressure values were 1283, 544, 239, 69, 18.2, and 9.3 kPa (186.12, 78.99, 34.60, 10.06, 2.64, and 0.91 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 1.5, 1.5, 1.1, 0.8, 0.6, and 0.6 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were greater than expected at scaled distances equal to or less than 1.59 $m/kg^{1/3}$ (4.0 $ft/lb^{1/3}$) and less than expected at scaled distances equal to or greater than 2.14 $m/kg^{1/3}$ (5.4 $ft/lb^{1/3}$). The scaled positive impulse values were 237, 145, 97, 57, 29.6, and 9.6 kPa-ms/$kg^{1/3}$ (26.46, 16.18, 10.77, 6.32, 3.29, and 1.07 psi-ms/$lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 8.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 1.7, 1.1, 0.9, 0.7, 0.7, and 0.4 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the single perforated M6 propellant in the dryer bed configuration were greater than expected at scaled distances equal to or less than 2.14 $m/kg^{1/3}$ (5.4 $ft/lb^{1/3}$) and less than expected at scaled diatances equal to or greater than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$). The pressure values were 1256, 574, 262, 75, 16.5, and 4.02 kPa (182.12, 83.19, 38.07, 10.94, 2.39, and 0.53 psi) at scaled diatances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 1.6, 1.3, 1.1, 0.9, 0.4, and 0.2 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were greater than expected at scaled distances equal to or less than 2.14 m/kg$^{1/3}$ (5.4 ft/lb$^{1/3}$) and less than expected at scaled distances equal to or greater than 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$). The scaled positive impulse values were 217, 155, 111, 65, 35, and 18.67 kPa-ms/kg$^{1/3}$ (24.22, 17.27, 12.35, 7.27, 3.85, and 2.08 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 1.5, 1.2, 1.1, 0.9, 0.9, and 1.1 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for multiperforated M6 propellant in the simulated dryer bed configuration were greater than expected at scaled distances equal to or less than 2.14 m/kg$^{1/3}$ (5.4 ft/lb$^{1/3}$) and less than expected at scaled distances equal to or greater than 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$). The pressure values were 1233, 537, 240, 71, 18.6, and 6.35 kPa (178.78, 77.90, 34.86, 10.31, 2.70, and 0.92 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 1.5, 1.3, 1.0, 0.7, 0.7, and 0.6 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were equal to or less than expected at all scaled distances of the experiment. The scaled positive impulse values were 162, 120, 89, 56, 31.2, and 17.03 kPa-ms/kg$^{1/3}$ (18.07, 13.37, 9.93, 6.20, 3.47, and 1.90 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 mkg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0 and 40.0 ft/lb$^{1/3}$), respectively. These values equate to 0.9, 0.8, 0.7, 0.7, 0.8, and 1.0 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) The critical depth of both single perforated and multiperforated M30A1 propellant was approximately 76.3 mm (3 inches).

(2) Pressure and scaled positive impulse scaled as a function of the cube root scaling law for both single and multiperforated propellant when similar geometries were compared.

Table 72. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for M30A1 Propellant (single-perforated) in a Cylindrical Shipping Container, L/D=1.7:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	217.95	1502.73	23.38	209.85	22.000	8.727	2.01	13.84	2.66	23.84
4.000	1.587	92.92	640.67	16.07	144.18	23.000	9.124	1.87	12.88	2.56	23.01
5.000	1.983	49.97	344.53	12.16	109.09	24.000	9.521	1.75	12.03	2.48	22.26
6.000	2.380	30.91	213.12	9.76	87.61	25.000	9.917	1.64	11.29	2.40	21.57
7.000	2.777	20.98	144.65	8.16	73.24	26.000	10.314	1.54	10.63	2.33	20.98
8.000	3.174	15.20	104.83	7.02	63.03	27.000	10.711	1.46	10.04	2.27	20.37
9.000	3.570	11.57	79.76	6.03	54.13	28.000	11.108	1.38	9.51	2.21	19.86
10.000	3.967	9.13	62.90	5.52	49.56	29.000	11.504	1.31	8.95	2.15	19.25
11.000	4.364	7.43	51.22	5.00	44.91	30.000	11.901	1.25	8.61	2.11	18.89
12.000	4.760	6.19	42.65	4.59	41.15	31.000	12.298	1.19	8.22	2.06	18.47
13.000	5.157	5.25	36.21	4.24	38.04	32.000	12.694	1.14	7.87	2.01	18.08
14.000	5.554	4.53	31.25	3.95	35.91	33.000	13.091	1.09	7.55	1.97	17.71
15.000	5.950	3.96	27.34	3.70	33.21	34.000	13.488	1.05	7.25	1.94	17.37
16.000	6.347	3.51	24.28	3.49	31.36	35.000	13.884	1.01	6.98	1.90	17.05
17.000	6.744	3.14	21.63	3.30	29.64	36.000	14.281	0.98	6.73	1.87	16.75
18.000	7.141	2.83	19.51	3.14	28.19	37.000	14.678	0.94	6.49	1.83	16.46
19.000	7.537	2.57	17.74	3.00	26.91	38.000	15.075	0.91	6.28	1.80	16.19
20.000	7.934	2.35	16.24	2.87	25.77	39.000	15.471	0.88	6.04	1.78	15.94
21.000	8.331	2.17	14.95	2.76	24.75	40.000	15.868	0.85	5.90	1.75	15.70

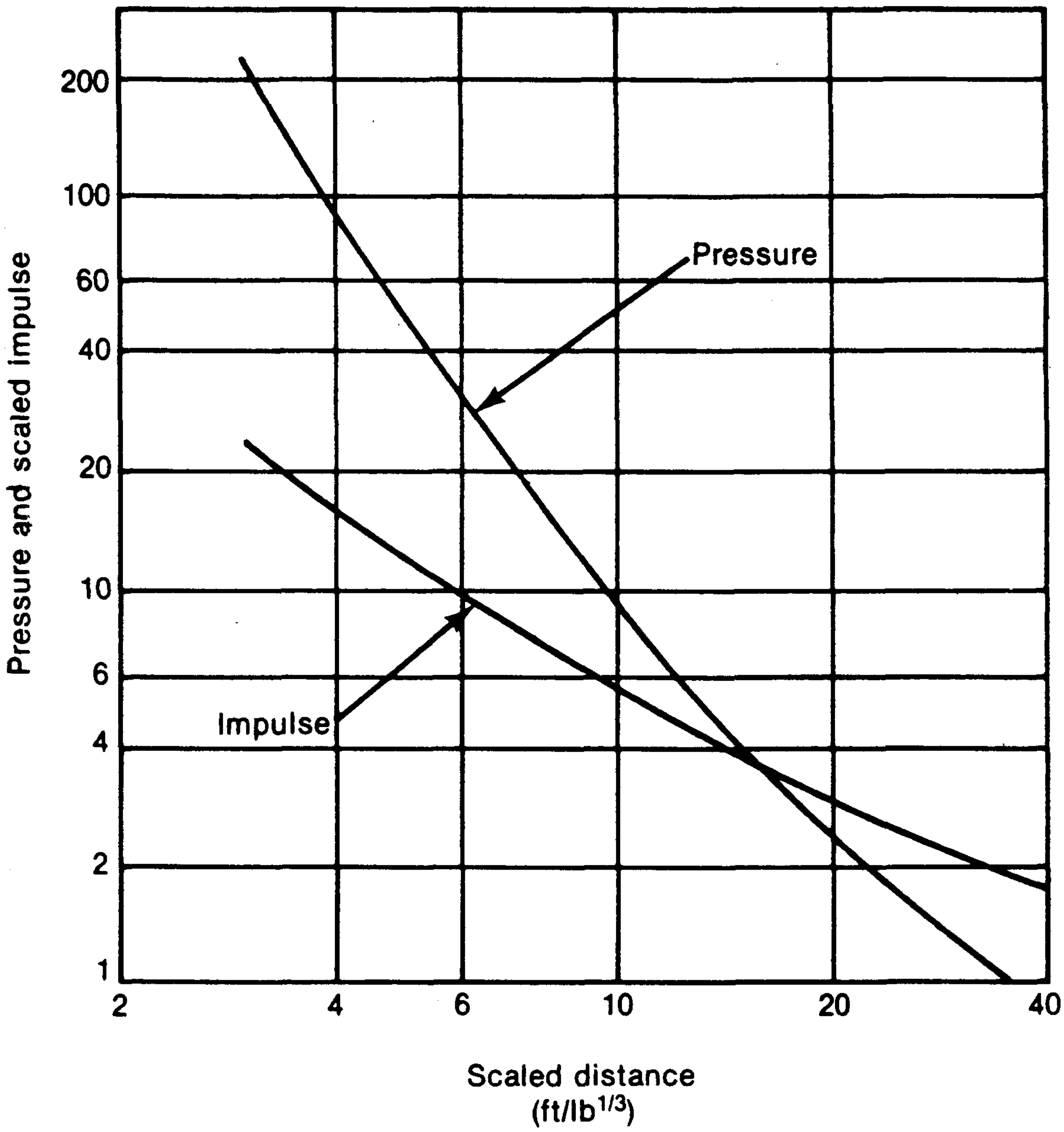


Figure 119. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for M30A1 Propellant (single-perforation) Cylindrical, L/D=1.7:1.

Table 73. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for M30A1 Propellant (multiperforated) in Cylindrical Configuration L/D=1.7:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	186.12	1283.31	26.46	277.49	22.000	8.727	1.92	13.27	2.63	23.64
4.000	1.587	78.89	543.94	16.18	145.18	23.000	9.124	1.80	12.43	2.50	22.41
5.000	1.983	42.45	292.70	11.85	106.35	24.000	9.521	1.70	11.69	2.37	21.25
6.000	2.380	26.36	181.76	9.52	85.45	25.000	9.917	1.60	11.04	2.25	20.17
7.000	2.777	17.99	124.07	8.07	72.40	26.000	10.314	1.52	10.46	2.13	19.15
8.000	3.174	13.13	90.52	7.06	63.39	27.000	10.711	1.44	9.95	2.03	18.20
9.000	3.570	10.06	69.37	6.32	56.70	28.000	11.108	1.38	9.49	1.93	17.29
10.000	3.967	8.01	55.20	5.74	51.47	29.000	11.504	1.32	9.07	1.83	16.44
11.000	4.364	6.56	45.23	5.26	47.21	30.000	11.901	1.26	8.69	1.74	15.64
12.000	4.760	5.51	37.96	4.86	43.63	31.000	12.298	1.21	8.35	1.66	14.88
13.000	5.157	4.71	32.48	4.52	40.55	32.000	12.694	1.17	8.04	1.58	14.16
14.000	5.554	4.10	28.25	4.22	37.86	33.000	13.091	1.12	7.75	1.50	13.48
15.000	5.950	3.61	24.91	3.95	35.46	34.000	13.488	1.09	7.49	1.43	12.84
16.000	6.347	3.22	22.21	3.71	33.36	35.000	13.884	1.05	7.25	1.36	12.23
17.000	6.744	2.90	20.01	3.49	31.35	36.000	14.281	1.02	7.03	1.30	11.56
18.000	7.141	2.64	18.18	3.29	29.55	37.000	14.678	0.99	6.82	1.24	11.11
19.000	7.537	2.41	16.35	3.11	27.90	38.000	15.075	0.96	6.63	1.18	10.59
20.000	7.934	2.23	15.35	2.94	26.38	39.000	15.471	0.94	6.46	1.12	10.10
21.000	8.331	2.06	14.23	2.78	24.96	40.000	15.868	0.91	6.29	1.07	9.63

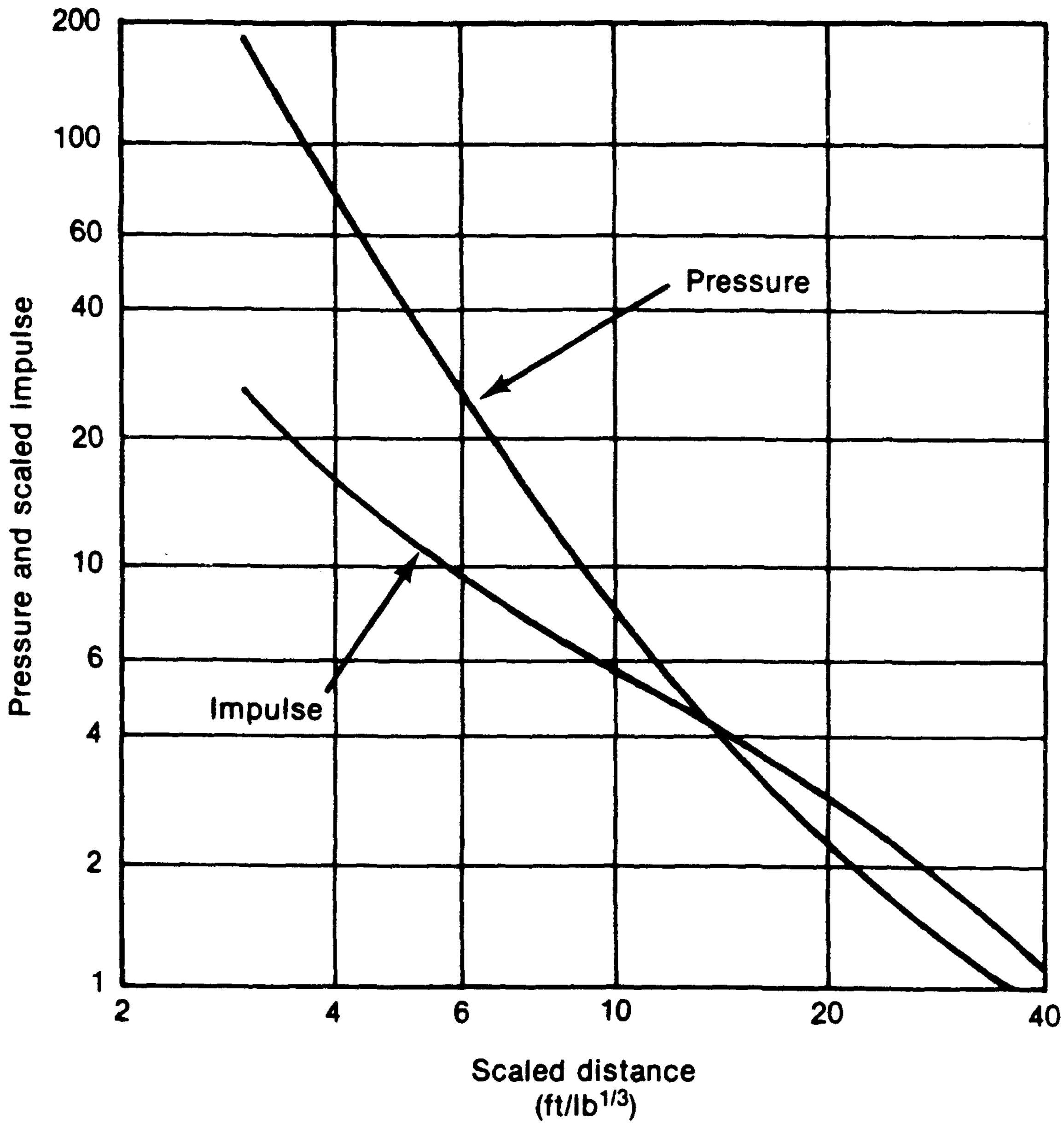


Figure 120. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for M30A1 Propellant (multiperforated) in Cylindrical Configuration, L/D=1.7:1.

Table 74. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for M30A1 Propellant (single-perforated) in Dryer Bed Orthorhombic Configuration.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	182.12	1255.72	24.22	217.35	22.000	8.727	1.66	11.00	3.26	29.24
4.000	1.587	83.19	573.60	17.27	154.98	23.000	9.124	1.46	10.08	3.14	28.22
5.000	1.983	46.36	319.63	13.44	120.57	24.000	9.521	1.35	9.28	3.04	27.27
6.000	2.380	29.18	201.21	11.02	98.94	25.000	9.917	1.24	8.58	2.94	26.41
7.000	2.777	19.94	137.49	9.38	84.13	26.000	10.314	1.15	7.96	2.85	25.61
8.000	3.174	14.45	99.63	8.18	73.39	27.000	10.711	1.08	7.41	2.77	24.88
9.000	3.570	10.94	75.45	7.27	65.25	28.000	11.108	1.00	6.92	2.70	24.20
10.000	3.967	8.57	59.11	6.56	58.88	29.000	11.504	0.94	6.49	2.63	23.56
11.000	4.364	6.90	47.59	5.99	53.75	30.000	11.901	0.88	6.09	2.56	22.97
12.000	4.760	5.68	39.18	5.52	49.54	31.000	12.298	0.83	5.74	2.50	22.41
13.000	5.157	4.76	32.84	5.13	46.01	32.000	12.694	0.79	5.41	2.44	21.89
14.000	5.554	4.06	27.96	4.79	43.02	33.000	13.091	0.74	5.12	2.39	21.40
15.000	5.950	3.50	24.12	4.51	40.46	34.000	13.488	0.70	4.85	2.33	20.95
16.000	6.347	3.05	21.04	4.26	38.22	35.000	13.884	0.67	4.61	2.29	20.51
17.000	6.744	2.69	18.54	4.04	36.27	36.000	14.281	0.64	4.38	2.24	20.10
18.000	7.141	2.39	16.48	3.85	34.54	37.000	14.678	0.61	4.18	2.20	19.72
19.000	7.537	2.14	14.75	3.68	33.00	38.000	15.075	0.58	3.99	2.16	19.35
20.000	7.934	1.93	13.30	3.52	31.62	39.000	15.471	0.56	3.84	2.12	19.00
21.000	8.331	1.75	12.06	3.38	30.37	40.000	15.868	0.53	3.65	2.08	18.67

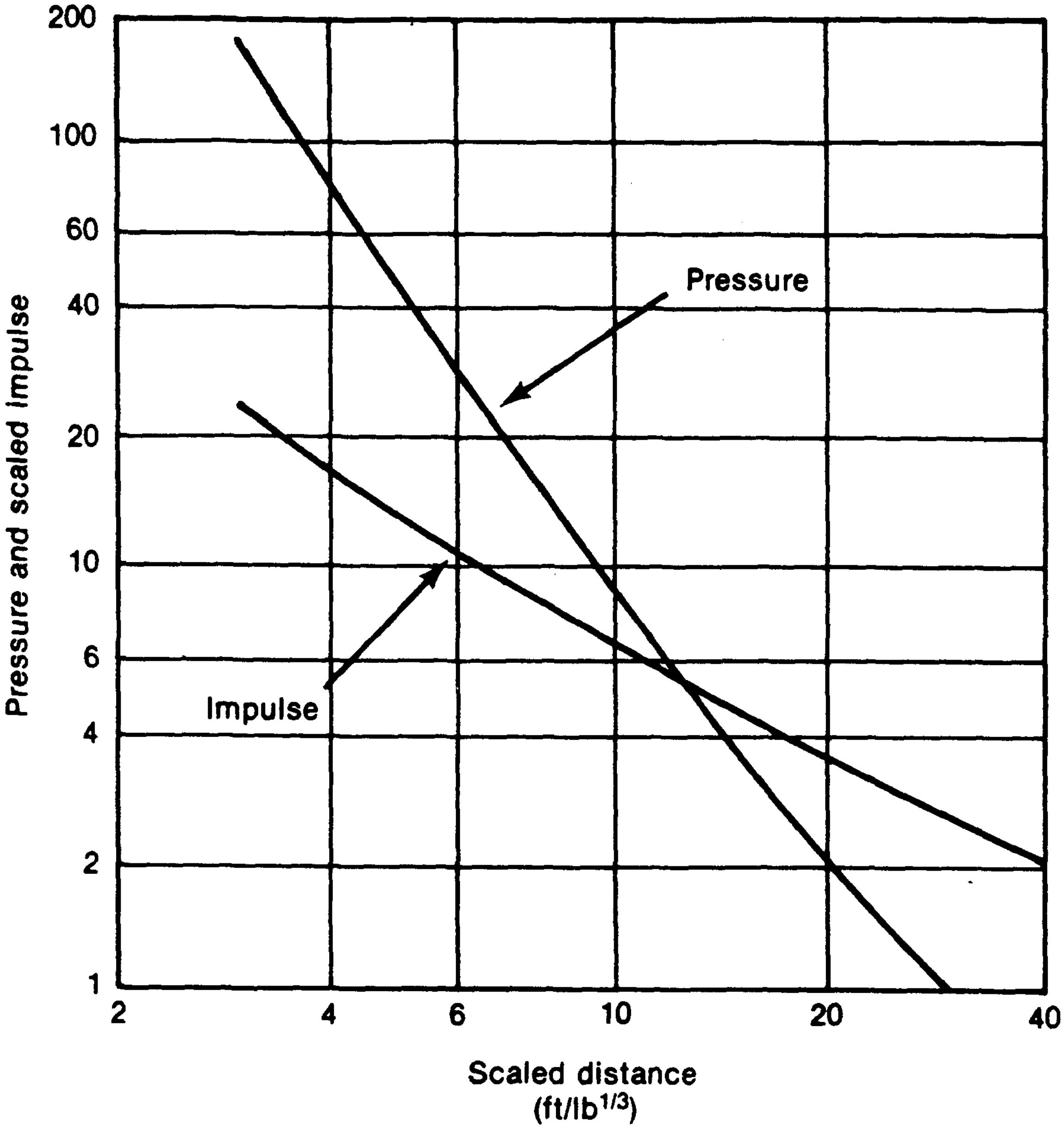


Figure 121. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for M30A1 Propellant (single-perforated) in an Orthorhombic Dryer Bed Configuration.

Table 75. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for M30A1 Propellant (multiperforated) Orthorhombic Dryer Bed Configuration.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	178.78	1232.67	18.07	162.15	22.000	8.727	1.96	13.54	2.97	26.61
4.000	1.587	77.90	537.13	13.37	120.02	23.000	9.124	1.84	12.67	2.87	25.72
5.000	1.983	45.58	293.58	10.70	96.06	24.000	9.521	1.73	11.91	1.77	24.89
6.000	2.380	26.69	184.03	8.98	80.61	25.000	9.917	1.63	11.24	2.69	24.13
7.000	2.777	18.32	126.35	7.78	69.80	26.000	10.314	1.54	10.64	2.61	23.42
8.000	3.174	13.42	92.52	6.89	61.80	27.000	10.711	1.47	10.11	2.54	22.76
9.000	3.570	10.31	71.06	6.20	55.64	28.000	11.108	1.40	9.64	2.47	22.14
10.000	3.967	8.21	56.62	5.65	50.73	29.000	11.504	1.34	9.21	2.40	21.57
11.000	4.364	6.73	46.43	5.21	46.73	30.000	11.901	1.28	8.82	2.34	21.03
12.000	4.760	5.65	38.98	4.84	43.40	31.000	12.298	1.23	8.47	2.29	20.52
13.000	5.157	4.84	33.35	4.52	40.59	32.000	12.694	1.18	8.14	2.23	20.05
14.000	5.554	4.20	28.99	4.25	38.17	33.000	13.091	1.14	7.85	2.18	19.60
15.000	5.950	3.70	25.55	4.02	36.07	34.000	13.488	1.10	7.58	2.14	19.17
16.000	6.347	3.30	22.77	3.81	34.23	35.000	13.884	1.06	7.33	2.09	18.77
17.000	6.744	2.97	20.50	3.63	32.60	36.000	14.281	1.03	7.11	2.05	18.38
18.000	7.141	2.70	18.61	3.47	31.15	37.000	14.678	1.00	6.90	2.01	18.02
19.000	7.537	2.47	17.03	3.33	29.84	38.000	15.075	0.97	6.70	1.97	17.67
20.000	7.934	2.28	15.69	3.19	28.66	39.000	15.471	0.95	6.52	1.93	17.34
21.000	8.331	2.11	14.54	3.07	27.59	40.000	15.868	0.92	6.35	1.90	17.03

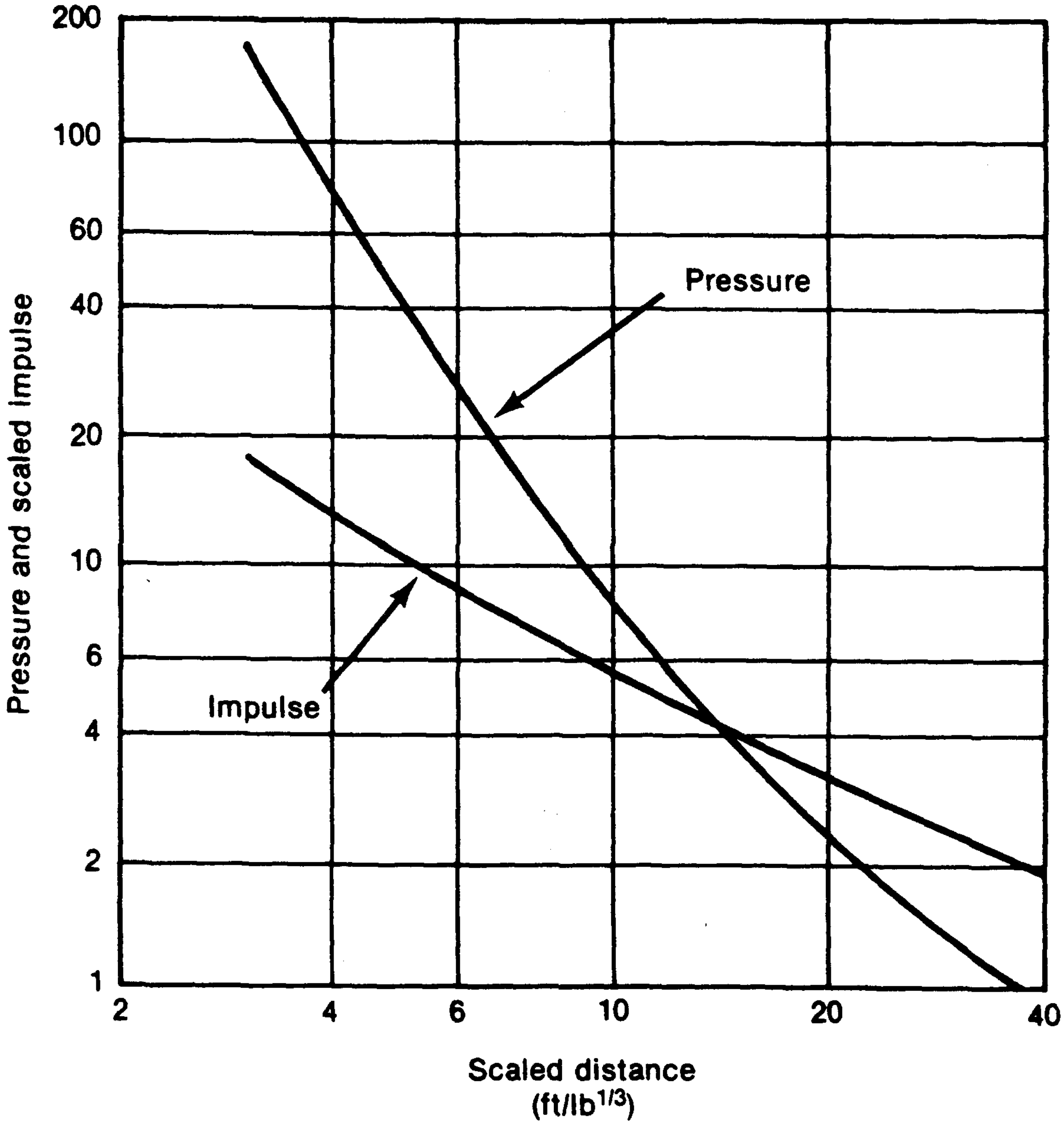


Figure 122. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for M30A1 Propellant (multiperforated) in an Orthorhombic Dryer Bed Configuration.

OBJECTIVE

The objective of these tests was to determine the maximum blast output in terms of peak pressure and positive impulse from the detonation of M31A1E1 propellant. The measured values were compared with known characteristics of hemispherical TNT surface bursts to determine the TNT equivalency.

MATERIAL

The test material, M31A1E1 slotted stick propellant, is a solvent, triple-base propellant which will be utilized in the M203E2 Propelling Charge (155 mm cannon). The chemical constituents by percentages are: nitrocellulose/nitroglycerine/nitroguanidine/dibutylphthlate/ethyl centralite/potassium sulfate/carbon black in percentages of 21.50/18.00/54.70/3.00/1.50/1.25/0.25, respectively. Propellant dimensions were: Length 736.6 mm (29 inches), Diameter 6.35 mm (0.250 inch), Perforation diameter 2.18 mm (0.086 inch) and web 2.08 mm (0.082 inch).

TEST SETUP

M31A1E1 Propellant was tested in configurations representative of in-process and shipping configurations in charge weights of 27.2 and 55.2 kg (60 and 120 lb). The physical characteristics are described as follows:

(1) An orthorhombic fiberboard container filled with 27.2 kg (60 lb).

(2) An orthorhombic fiberboard container inside a plywood container in 55.3 kg (120 lb).

INSTRUMENTATION

Twelve side-on pressure transducers were flush mounted to the ground surface in two sand-filled runways in a 90-degree array. Scaled distances ranged from 1.19 to 15.87 m/kg$^{1/3}$ (3.0 to 40.0 ft/lb$^{1/3}$) and remained constant throughout the experiments.

RESULTS

The results of the 27.2 kg (60 lb) tests are given in Table 76 and Figure 123. The results of the of the 55.7 kg (120 lb) tests are given in Table 77 and Figure 124.

DISCUSSION

The pressure values of the 27.2 kg (60 lb) of M31A1E1 propellant in scaled shipping container were greater than or equal to the expected values at scaled distances equal to or less than 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$) and less than expected at scaled distances equal to or greater than 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$). The pressure values were 1475, 625, 277, 79, 20, and 6.95 kPa (213.93, 90.59, 39.88, 11.47, 2.97 and 1.01 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressures equate to 2.1, 1.6, 1.6, 1.0, 0.8, and 0.6 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were greater than expected at a scaled distance of 1.19 $m/kg^{1/3}$ (3.0 $ft/lb^{1/3}$) less than expected at a scaled distance of 1.59 $m/kg^{1/3}$ (4.0 $ft/lb^{1/3}$), greater than expected at a scaled distance of 2.14$m/kg^{1/3}$ (5.4 $ft/lb^{1/3}$) and less than expected at scaled distances equal to or greater than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$). The scaled positive impulse values were 193, 139, 98, 54, 25, and 9.79 kPa-$ms/kg^{1/3}$ (21.49, 15.44, 10.88, 6.07, 2.73, and 1.09 psi-$ms/lb^{1/3}$), respectively. These scaled positive impulse values equate to 1.3, 0.9, 1.2, 0.7, 0.4, and 0.4 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the 55.3 kg (120 lb) M31A1E1 propellant in standard shipping box were greater than expected at scaled distances equal to or less than 2.14 $m/kg^{1/3}$ (5.4 $ft/lb^{1/3}$) and less than expected at scaled distances equal to or greater than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$). The pressure values were 1372, 549, 231, 66, 19, and 8.11 kPa (198.93, 79.60, 33.57, 9.59, 2.71, and 1.19 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 1.6, 1.4, 1.3, 0.5, 0.9, and 0.8 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were greater than expected at a scaled distance of 1.19 $m/kg^{1/3}$ (3.0 $ft/lb^{1/3}$) and less than expected at all other scaled distances of the experiment. The scaled positive impulse values were 156, 118, 89, 54, 28, and 13.02 kPa-$ms/kg^{1/3}$ (17.36, 13.17, 9.88, 6.06, 3.12, and 1.45 psi-$ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 1.6, 0.7, 0.6, 0.6, 0.5, and 0.7 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) M31A1E1 Propellant, when detonated can generate peak presdsure in excess of equal amounts of TNT at scaled distances equal to or less than 2.14 $m/kg^{1/3}$ (5.4 $ft/lb^{1/3}$).

(2) The blast output from M31A1E1 is dependant upon the configuration from which it is tested.

(3) To within experimental limits, blast pressure and impulse scale as a function of the charge weight.

Table 76. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for M31A1E1 Propellant in Orthorhombic Shipping Container.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	213.92	1474.95	21.49	192.85	22.000	8.727	2.18	15.07	2.16	19.39
4.000	1.587	90.67	625.20	15.42	138.42	23.000	9.124	2.05	14.10	2.05	18.42
5.000	1.983	48.77	336.29	11.93	107.02	24.000	9.521	1.92	13.26	1.95	17.54
6.000	2.380	30.27	208.70	9.66	86.73	25.000	9.917	1.81	12.51	1.86	16.74
7.000	2.777	20.65	142.36	8.09	72.61	26.000	10.314	1.72	11.85	1.78	16.00
8.000	3.174	15.05	103.79	6.94	62.25	27.000	10.711	1.63	11.26	1.71	15.32
9.000	3.570	11.53	79.48	6.06	54.35	28.000	11.108	1.56	10.73	1.64	14.69
10.000	3.967	9.16	63.19	5.36	48.13	29.00	11.504	1.49	10.26	1.57	14.10
11.000	4.364	7.51	51.75	4.81	43.12	30.000	11.901	1.42	9.82	1.51	13.56
12.000	4.760	6.29	43.40	4.35	39.01	31.000	12.298	1.37	9.43	1.46	13.06
13.000	5.157	5.38	37.11	3.96	35.57	32.000	12.694	1.32	9.08	1.40	12.59
14.000	5.554	4.68	32.25	3.64	32.66	33.000	13.091	1.27	8.75	1.35	12.15
15.000	5.950	4.12	28.41	3.36	29.70	34.000	13.488	1.23	8.45	1.31	11.74
16.000	6.347	3.67	25.32	3.12	28.00	35.000	13.884	1.19	8.17	1.27	11.36
17.000	6.744	3.31	22.79	2.91	26.11	36.000	14.281	1.15	7.92	1.22	10.99
18.000	7.141	3.00	20.70	2.72	24.44	37.000	14.678	1.12	7.73	1.19	10.65
19.000	7.537	2.75	18.94	2.56	22.96	38.00	15.075	1.08	7.47	1.15	10.33
20.000	7.934	2.53	17.45	2.41	21.65	39.000	15.471	1.05	7.27	1.12	10.02
21.000	8.331	2.35	16.17	2.28	20.46	40.000	15.868	1.03	7.08	1.08	9.74

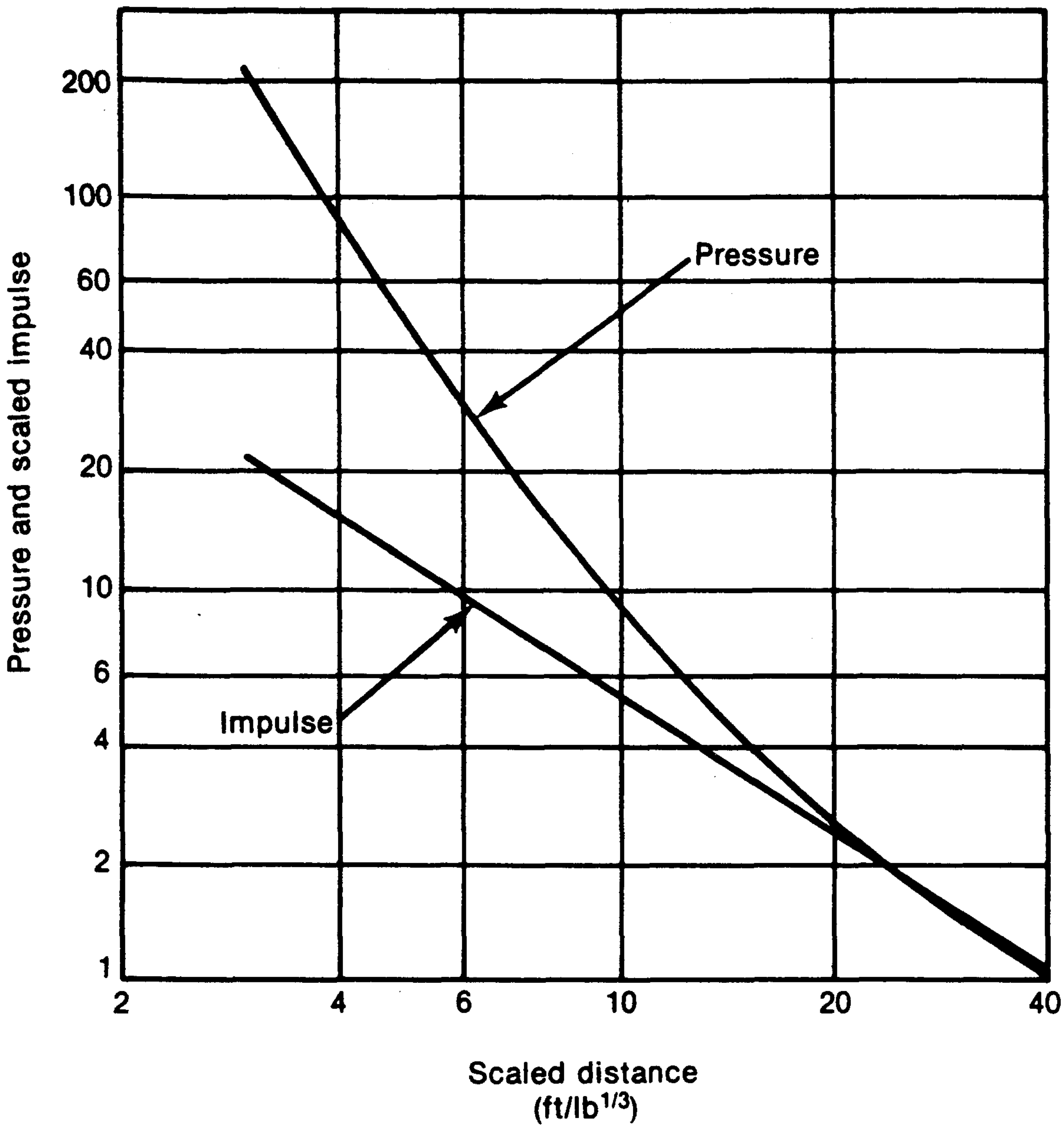


Figure 123. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for M31A1E1 Propellant in Orthorhombic Configuration 11.34 kg.

Table 77. Summary of Results for hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for M31A1E1 Propellant in Orthorhombic Configuration 54.43 kg.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	198.93	1371.64	17.36	155.76	22.000	8.727	2.06	14.22	2.57	23.08
4.000	1.587	79.60	548.87	13.17	118.73	23.000	9.124	1.95	13.46	2.47	22.12
5.000	1.983	41.52	286.28	10.64	95.47	24.000	9.521	1.86	12.80	2.37	21.24
6.000	2.380	25.36	174.82	8.93	80.17	25.000	9.917	1.77	12.22	2.28	20.42
7.000	2.777	17.17	118.38	7.71	69.16	26.000	10.314	1.70	11.70	2.19	19.67
8.000	3.174	12.50	86.16	6.78	60.85	27.000	10.711	1.63	11.25	2.11	18.97
9.000	3.570	9.59	66.12	6.06	54.36	28.000	11.108	1.57	10.84	2.04	18.32
10.000	3.967	7.66	52.82	5.48	49.14	29.000	11.504	1.52	10.47	1.97	17.72
11.000	4.364	6.32	43.54	5.00	44.85	30.000	11.901	1.47	10.14	1.91	17.15
12.000	4.760	5.34	36.85	4.60	41.26	31.000	12.298	1.43	9.84	1.85	16.62
13.000	5.157	4.61	31.76	4.26	38.22	32.000	12.694	1.39	9.57	1.80	16.12
14.000	5.554	4.04	27.87	3.97	35.60	33.000	13.091	1.35	9.32	1.74	15.65
15.000	5.950	3.60	24.80	3.71	33.32	34.000	13.488	1.32	9.10	1.70	15.21
16.000	6.347	3.24	22.34	3.49	31.32	35.000	13.884	1.29	8.90	1.65	14.80
17.000	6.744	2.95	20.33	3.29	29.55	36.000	14.281	1.26	8.71	1.60	14.40
18.000	7.141	2.71	18.67	3.12	27.98	37.000	14.678	1.24	8.54	1.56	14.03
19.000	7.537	2.51	17.28	2.96	26.57	38.000	15.075	1.22	8.38	1.52	13.67
20.000	7.934	2.33	16.10	2.82	25.29	39.000	15.471	1.19	8.24	1.49	13.34
21.000	8.331	2.19	15.09	2.69	24.14	40.000	15.868	1.18	8.11	1.45	13.02

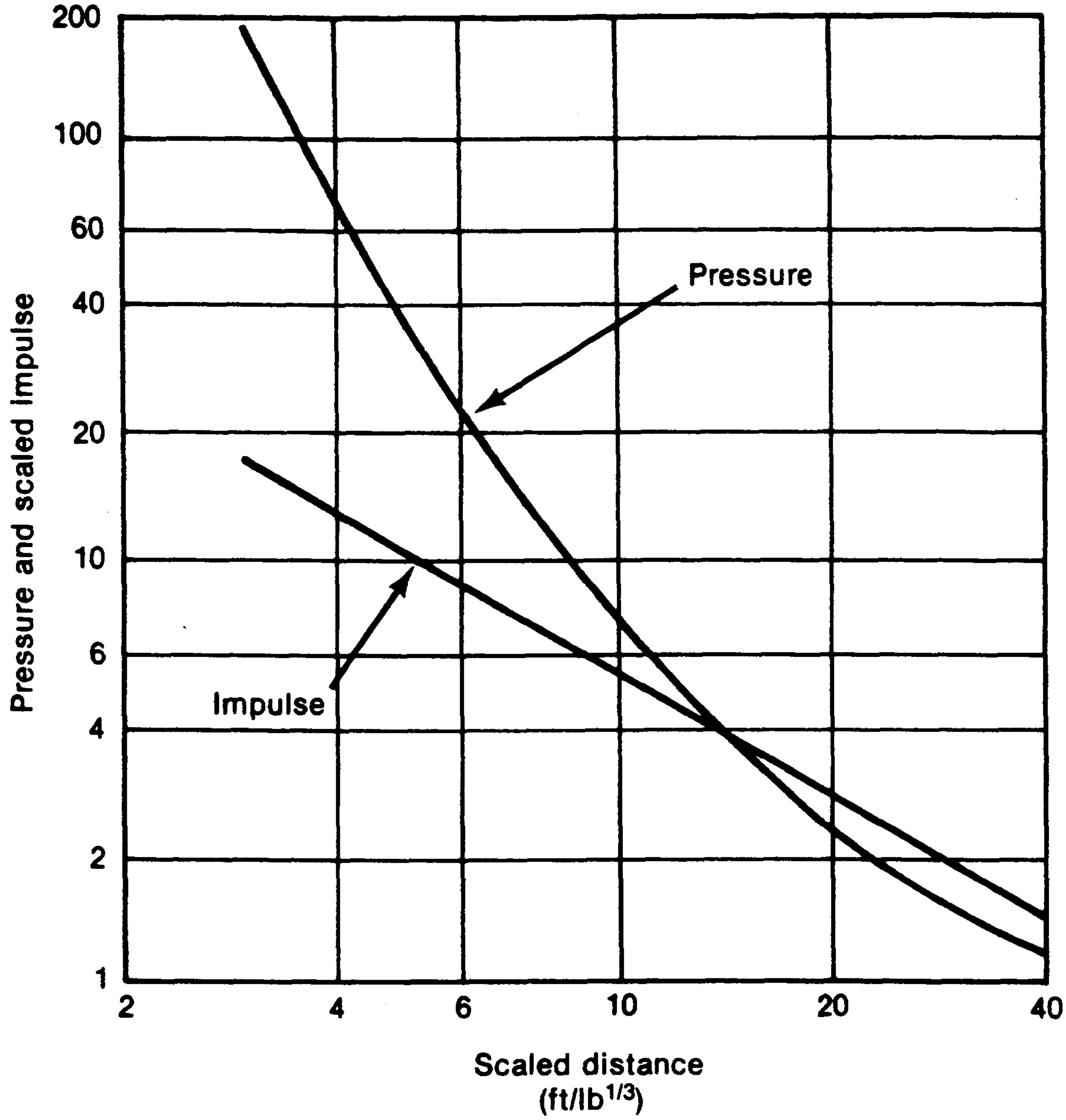


Figure 124. Peak Presure and Scaled Positive Impulse Versus Scaled Distance for M31A1E1 Propellant in Orthorhombic Configuration 54.43 kg (120 Lb).

OBJECTIVE

The objectives of this study were to determine the maximum airblast output in terms of peak pressure and positive impulse for N5 propellant in various in-plant configurations. The measured values were compared to the known characteristics of hemispherical TNT surface bursts and the TNT equivalency was determined.

MATERIALS

N5 propellant is a single base propellant. The ingredients of N5 propellant are 50% nitrocellulose, 35% nitroglycerine and 10.5% diethylphtalate. The remaining ingredients are not reported. The density of the propellant is 1.55 g/cm^3. The reported igniton temperature is 210 °C, heat of explosion was 850 cal/g and a heat of formation of -521 cal/g. The propellant was insensitive to impact of 64 cm using the Bureau of Mines impact apparatus. Detonation velocity was determined by Allegany Ballistics Laboratory determined that confined N5 propellant detonation velocity was 7010 m/s and unconfined the reported value was 6916 m/s. The propellant was tested in several different configurations. It was tested as a Mk 43-1 rocket grain, in carpet rolls, strips, paste with various percentages of moisture, and in conveyer strips.

TEST SETUP

(1) The 2.75-inch Rocket Grain Mk 43-1 was tested in shelves holding one, seven, and nine rocket grains. Each grain weighed 2.83 kg (6.25 lb).

(2) Tests were conducted on cylindrically shaped rolls of N5 sheet propellant 101.6 mm (4 inches) wide by 1.9 mm (0.075 inch) thick in various lengths. They were tested in a coiled carpet-roll in various diameters.

(3) Each strip was 7.62 m (25 ft) long by 101.6 mm (4 inches) wide by 1.9 mm (0.075 inch) thick.

(4) Fiber shipping drums containing a paste made from N5 propellant and 10% water were tested. A hole was made in the bottom of the drum to insert the booster and the blasting cap. The drum was elevated to clear the blasting cap lead wires.

(5) N5 propellant was loaded into charging buckets or on a conveyor line to simulate two different size rectangular boxes fabricated from plywood.

INSTRUMENTATION

The instrumentation system used was similar to the system described in the Chapter entitled "Nitroglycerine", and is shown in Figure 36.

RESULTS

The results of the shipping container with N5 paste and 10% moisture are shown in Table 78 and Figure 125. The results of the N5 propellant carpet rolls are given in Table 79 and Figure 126. The charge bucket test results are given in Table 80 and Figure 127. The conveyor belt configuration test results are given in Table 81 and Figure 128. The results of the 2.75 Inch Rocket Grain Mk 43-1 are given in Table 82 and Figure 129.

DISCUSSION

Tests were conducted in addition to the blast measurement tests. The additional tests included attempts to detonate N5 propellant in flat sheets and in slurry mixtures with up to 88% moisture. An attempt to determine the critical depth and sympathetic detonation of rocket grains in vee-shaped shelves were also conducted. The results of the N5 tests on sheets indicated that a single sheet laying flat will not detonate. N5 slurry with 88% moisture failed to mass detonate under strong confinement. Unconfined N5 propellant has a critical depth of 19.05 mm (0.75 inch) when initiated by a very strong booster such as Composition C4 high explosive. Sympathetic detonation tests between rocket grains were inconclusive in the configuration. There is a possibility that sympahethic detonation is possible for the Mk 43-1 Rocket Grains in a vee-shaped shelves with a spacing of less than 152.4 mm (6 inches). Details of the specific tests and the results are given in the orginal test report cited.

Blast pressure and scaled positive impulse data for the tests and test configurations where the N5 propellant exhibited characteristics of mass detonation are covered below.

The pressure values for the N5 propellant with 10% moisture in the shipping containers were equal to the expected values at a scaled distance of 1.19 m/kg$^{1/3}$ (3.0 ft/lb$^{1/3}$) and less than equal amounts of TNT at scaled distances equal to or greater than 1.59 m/kg$^{1/3}$ (4.0 ft/lb$^{1/3}$). The pressure values were 939, 424, 198, 64, 18.8, and 7.45 kPa (136.18, 61.46, 28.76, 9.26, 2.73, and 1.08 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 1.0, 0.9, 0.8, 0.7, 0.6, and 0.8 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were less than expected at all scaled distances of the experiment. The scaled positive impulse values were 163, 123, 92, 56, 28.6, and 13.19 kPa-ms/kg$^{1/3}$ (18.15, 13.73, 10.26, 6.25, 3.19, and 1.47 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.9, 0.9, 0.8, 0.7, 0.7, and 0.7 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the N5 propellant in carpet rolls were greater than expected at scaled distances equal to or less than 2.38 m/kg$^{1/3}$ (6.0 ft/lb$^{1/3}$) and less than expected at scaled distances equal to or greater than 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$). The pressure values were 1247, 529, 232, 67, 17.51, and 9.75 kPa (180.82, 76.74, 33.67, 9.77, 2.54, and 0.86 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 1.4, 1.3, 1.2, 0.6, 0.5, and 0.4 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were greater than expected at scaled distances equal to or less than 1.59 m/kg$^{1/3}$ (4.0 ft/lb$^{1/3}$) and less than expected at scaled distances equal to or greater than 2.14 m/kg$^{1/3}$ (5.4 ft/lb$^{1/3}$). The scaled positive impulse values were 213, 137, 96, 60, 32.09, and 9.75 kPa-ms/kg$^{1/3}$ (23.77, 15.30, 10.68, 6.66, 3.58, and 1.09 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 1.3, 1.1, 0.9, 0.8, 0.8, and 0.6 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the N5 propellant in the charge bucket configuration were equal to the expected values at a scaled diatance of 1.19 m/kg$^{1/3}$ (3.0 ft/lb$^{1/3}$) and less than expected at scaled distances equal to or greater than 1.59 m/kg$^{1/3}$ (4.0 ft/lb$^{1/3}$). The pressure values were 896, 402, 187, 61, 18.59, and 7.8 kPa (129.92, 58.27, 27.17, 8.8, 2.7, and 1.13 psi) at scaled distances of 1.19, 1.59 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 1.0, 0.9, 0.7, 0.6, 0.6, and 0.9 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were equal to the expected values at a scaled diatance of 1.19 m/kg$^{1/3}$ (3.0 ft/lb$^{1/3}$) and less than expected at all other scaled distances of the experiment. The scaled positive impulse values were 169, 122, 88, 54, 29.57, and 16.93 kPa-ms/kg$^{1/3}$ (18.88, 13.62, 9.87, 5.97, 3.29, and 1.89 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 1.0, 0.9, 0.7, 0.7, 0.7, and 0.9 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for N5 propellant with 10% moisture in the conveyor belt configuration were less than expected at all scaled distances of the experiment. The pressure values were 553, 269, 136, 49, 17, and 7.73 kPa (80.14, 39.07, 19.70, 7.16, 2.47, and 1.12 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0 and 40.0, ft/lb$^{1/3}$), respectively. These pressure values equate to 0.6, 0.5, 0.5, 0.5, 0.5, and 0.9 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were less than expected at all scaled distances of the experiment. The scaled positive impulse values were 111, 90, 72, 49. 28.98 and 15.91 kPa-ms/kg$^{1/3}$ (12.40, 9.99, 7.98, 5.43, 3.23, and 1.77 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.5, 0.4, 0.5, 0.6, 0.7, and 0.9 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the 2.75 Inch Rocket Grain Mk 43-1 were less than expected at a scaled distance of 1.19 m/kg$^{1/3}$ (3.0 ft/lb$^{1/3}$), greater than expected at scaled distances of 1.59, 2.14, 3.57, and 7.14 $m/kg^{1/3}$ (4.0, 5.4, 9.0, and 18.0 $ft/lb^{1/3}$) and less than expected at a scaled distance of 15.87 $m/kg^{1/3}$ (40.0 $ft/lb^{1/3}$). The pressure values were 845, 476, 265, 100, 28.6, and 1.06 kPa (122.57, 69.04, 38.41, 14.57, 4.15, and 1.06 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 0.9, 1.0, 1.2, 1.4, 1.3, and 0.8 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse value were less than expected at scaled distances equal to or less than 1.59 $m/kg^{1/3}$ (4.0 $ft/lb^{1/3}$), greater than expected at scaled distances of 2.14 and 3.57 $m/kg^{1/3}$ (5.4 and 9.0 $ft/lb^{1/3}$) and less than expected at scaled distances equal to or greater than 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$). The scaled positive impulse values were 115, 123. 114, 77, 35.33, and 16.38 kPa-$ms/kg^{1/3}$ (12.80, 13.72, 12.69, 8.59, 3.92, and 1.83 psi-$ms/lb^{1/3}$), respectively. These scaled positive impulse values equate to 0.8, 0.9, 1.1, 1.2, 0.9, and 0.9 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) Burning N5 propellant can transition to a detonation if confined by steel.

(2) N5 propellant paste with as much as 30% moisture can be detonated.

(3) N5 propellant carpet rolls can detonate.

(4) Sympathetic detonation of neighboring Mk 43-1, 2.75 inch rocket grains in vee-shaped shelves with a spacing of less than 152.4 mm (6 inches) may occur.

(5) N5 propellant is sheets will not transition to a detonation.

(6) N5 propellant slurry with 88% moisture will not detonate under strong confinement.

(7) Unconfined N5 propellant has a critial depth of 19.05 mm (0.75 inch) when intitiated with a very strong booster.

(8) There is insufficient evidence to prove that N5 propellant follows the scaling laws for blast pressure.

Table 78. **Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for N5 Propellant in Shipping Containers with 10% Moisture.**

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	136.18	938.93	18.15	162.88	22.000	8.727	2.06	14.18	2.63	23.56
4.000	1.587	61.46	423.78	13.73	123.20	23.000	9.124	1.94	13.37	2.51	22.57
5.000	1.983	34.71	239.31	11.06	99.22	24.000	9.521	1.84	12.67	2.41	21.65
6.000	2.380	22.39	154.41	9.26	83.13	25.000	9.917	1.75	12.04	2.32	20.81
7.000	2.777	15.77	108.75	7.98	71.58	26.000	10.314	1.67	11.48	2.23	20.04
8.000	3.174	11.81	81.44	7.01	62.88	27.000	10.711	1.59	10.98	2.15	19.32
9.000	3.570	9.26	63.82	6.25	56.09	28.000	11.108	1.53	10.54	2.08	18.65
10.000	3.967	7.51	51.77	5.64	50.64	29.000	11.504	1.47	10.13	2.01	18.02
11.000	4.364	6.26	43.15	5.14	46.17	30.000	11.901	1.42	9.77	1.94	17.44
12.000	4.760	5.33	36.77	4.73	42.43	31.000	12.298	1.37	9.43	1.88	16.89
13.000	5.157	4.63	31.89	4.37	39.26	32.000	12.694	1.32	9.13	1.83	16.38
14.000	5.554	4.07	28.08	4.07	36.53	33.000	13.091	1.28	8.85	1.77	15.90
15.000	5.950	3.63	25.04	3.81	34.17	34.000	13.488	1.25	8.60	1.72	15.44
16.000	6.347	3.27	22.56	3.58	32.09	35.000	13.884	1.21	8.37	1.67	15.02
17.000	6.744	2.98	20.53	3.37	30.26	36.000	14.281	1.18	8.15	1.63	14.61
18.000	7.141	2.73	18.82	3.19	28.63	37.000	14.678	1.15	7.96	1.59	14.23
19.000	7.537	2.52	17.38	3.03	27.16	38.000	15.075	1.13	7.77	1.54	13.86
20.000	7.934	2.34	16.16	2.88	25.85	39.000	15.471	1.10	7.60	1.51	13.52
21.000	8.331	2.19	15.10	2.75	24.65	40.000	15.868	1.08	7.45	1.47	13.19

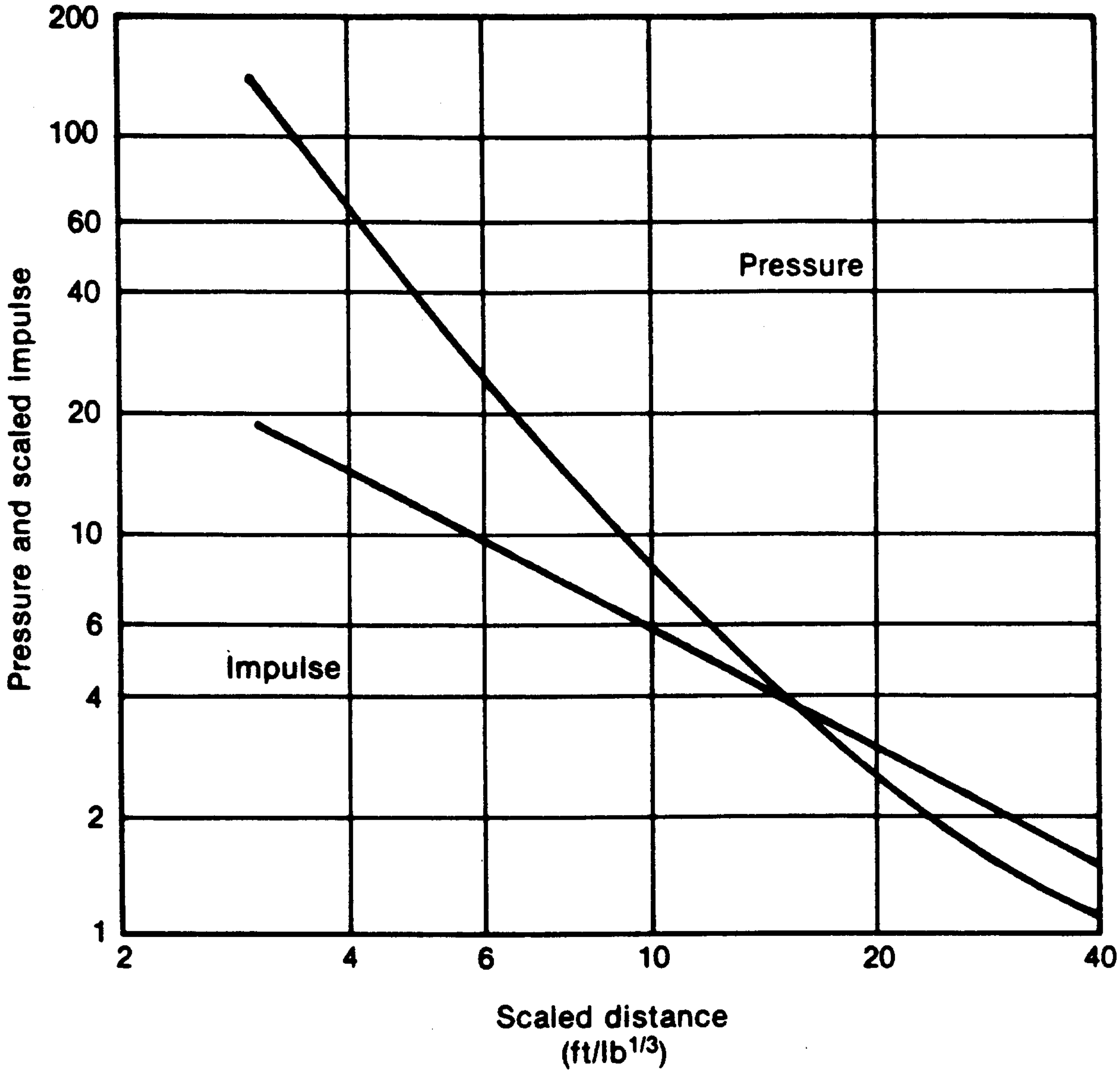


Figure 125. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for N5 Propellant in Cylindrical Shipping Containers with 10% Moisture.

Table 79. **Summary of Results for Hemispherical Surface Bursts, Peak Pressure and Scaled Positive Impulse for N5 Propellant Carpet Rolls with L/D=0.58:1.**

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	180.82	1246.78	23.77	213.32	22.000	8.727	1.85	12.73	2.84	25.52
4.000	1.587	76.74	529.14	15.30	137.28	23.000	9.124	1.73	11.92	2.69	24.14
5.000	1.983	41.31	284.81	11.62	104.25	24.000	9.521	1.62	11.20	2.54	22.84
6.000	2.380	25.65	176.82	9.58	86.00	25.000	9.917	1.53	10.57	2.41	21.61
7.000	2.777	17.50	120.63	8.28	74.32	26.000	10.314	1.45	10.01	2.28	20.46
8.000	3.174	12.76	87.95	7.36	66.06	27.000	10.711	1.38	9.51	2.16	19.38
9.000	3.570	9.77	67.35	6.66	59.78	28.000	11.108	1.31	9.06	2.05	18.35
10.000	3.967	7.77	53.54	6.10	54.75	29.000	11.504	1.25	8.65	1.94	17.39
11.000	4.364	6.36	43.84	5.63	50.56	30.000	11.901	1.20	8.29	1.84	16.48
12.000	4.760	5.33	36.76	5.23	46.97	31.000	12.298	1.15	7.95	1.74	15.63
13.000	5.157	4.56	31.42	4.88	43.82	32.000	12.694	1.11	7.65	1.65	14.82
14.000	5.554	3.96	27.30	4.57	41.01	33.000	13.091	1.07	7.38	1.57	14.05
15.000	5.950	3.49	24.05	4.29	38.48	34.000	13.488	1.03	7.12	1.49	13.33
16.000	6.347	3.11	21.43	4.03	36.17	35.000	13.884	1.00	6.89	1.41	12.65
17.000	6.744	2.80	19.29	3.79	34.05	36.000	14.281	0.97	6.67	1.34	12.00
18.000	7.141	2.54	17.51	3.58	32.09	37.000	14.678	0.94	6.47	1.27	11.39
19.000	7.537	2.32	16.02	3.37	30.28	38.000	15.075	0.91	6.29	1.21	10.81
20.000	7.934	2.14	14.75	3.19	28.58	39.000	15.471	0.89	6.12	1.14	10.27
21.000	8.331	1.98	13.67	3.01	27.00	40.000	15.868	0.86	5.96	1.09	9.75

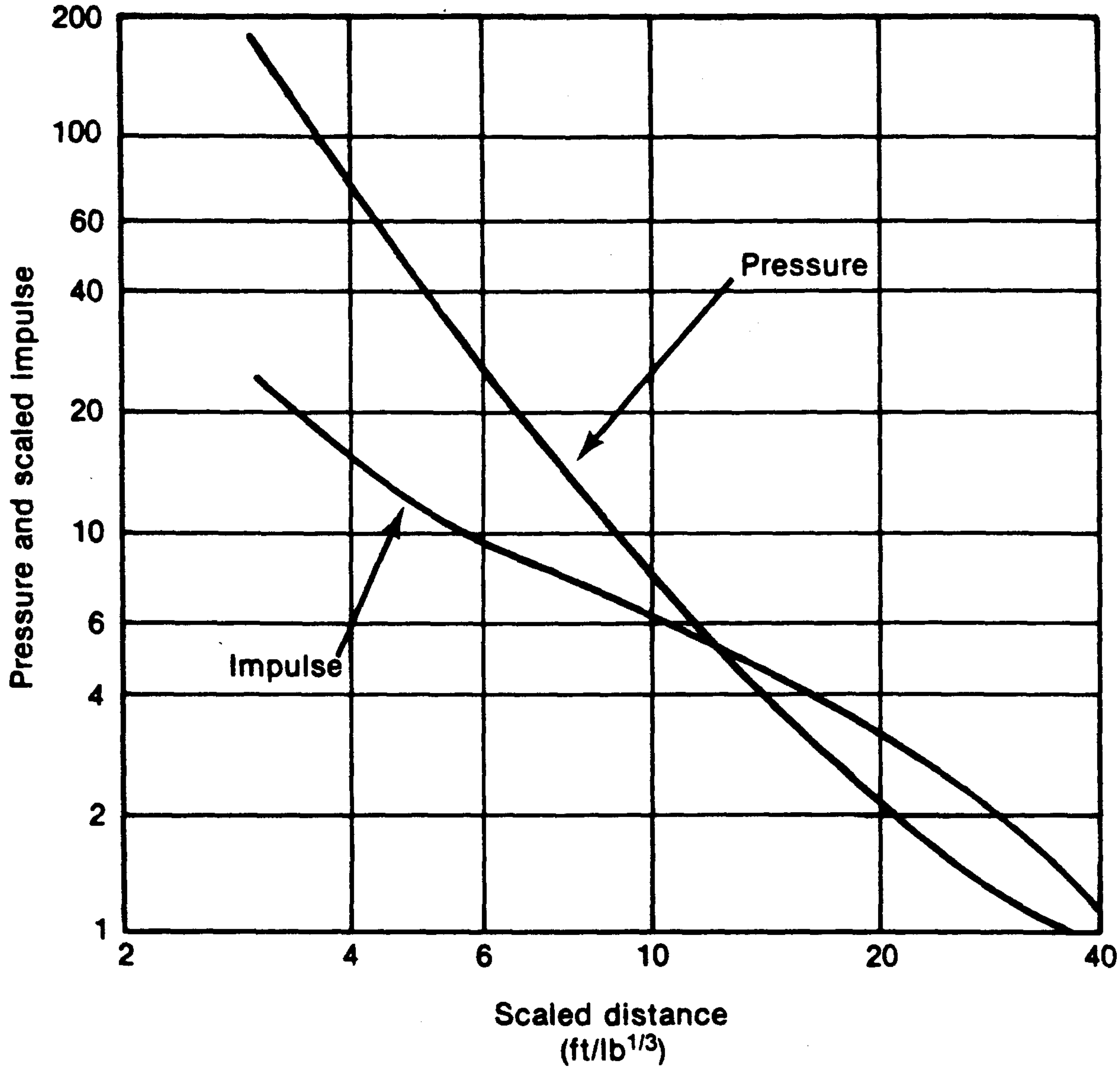


Figure 126. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for N5 Propellant in Carpet Rolls L/D=0.58:1.

Table 80. **Summary of Results for Hemispherical Surface Bursts, Peak Pressure and Scaled Positive Impulse for N5 Propellant in Charge Buckets.**

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	129.92	895.77	18.88	169.44	22.000	8.727	2.06	14.22	2.83	25.38
4.000	1.587	58.27	401.79	13.62	122.25	23.000	9.124	1.95	13.46	2.74	24.56
5.000	1.983	32.80	226.18	10.70	96.06	24.000	9.521	1.86	12.79	2.65	23.81
6.000	2.380	21.15	145.85	8.86	79.51	25.000	9.917	1.77	12.20	2.58	23.12
7.000	2.777	14.91	102.83	7.59	68.14	26.000	10.314	1.69	11.67	2.51	22.49
8.000	3.174	11.20	77.20	6.67	54.86	27.000	10.711	1.62	11.20	2.44	21.90
9.000	3.570	8.80	60.69	5.97	53.56	28.000	11.108	1.56	10.77	2.38	21.36
10.000	3.967	7.17	49.41	5.42	48.61	29.000	11.504	1.51	10.39	2.32	20.85
11.000	4.364	6.00	41.36	4.97	44.62	30.000	11.901	1.46	10.04	2.27	20.37
12.000	4.760	5.13	35.39	4.61	41.34	31.000	12.298	1.41	9.72	2.22	19.93
13.000	5.157	4.47	30.83	4.30	38.58	32.000	12.694	1.37	9.43	2.17	19.52
14.000	5.554	3.95	27.26	4.04	36.24	33.00	13.091	1.33	9.16	2.13	19.13
15.000	5.950	3.54	24.42	3.81	34.23	34.000	13.488	1.29	8.92	2.09	18.76
16.000	6.347	3.21	22.10	3.62	32.47	35.000	13.884	1.26	8.70	2.05	18.41
17.000	6.744	2.93	20.19	3.45	30.93	36.000	14.281	1.23	8.49	2.02	18.08
18.000	7.141	2.70	18.59	3.29	29.57	37.000	14.678	1.20	8.30	1.98	17.77
19.000	7.537	2.50	17.24	3.16	28.35	38.000	15.075	1.18	8.12	1.95	17.48
20.000	7.934	2.33	16.09	3.04	27.26	39.000	15.471	1.15	7.96	1.92	17.20
21.000	8.331	2.19	15.09	2.93	26.27	40.000	15.868	1.13	7.80	1.89	16.93

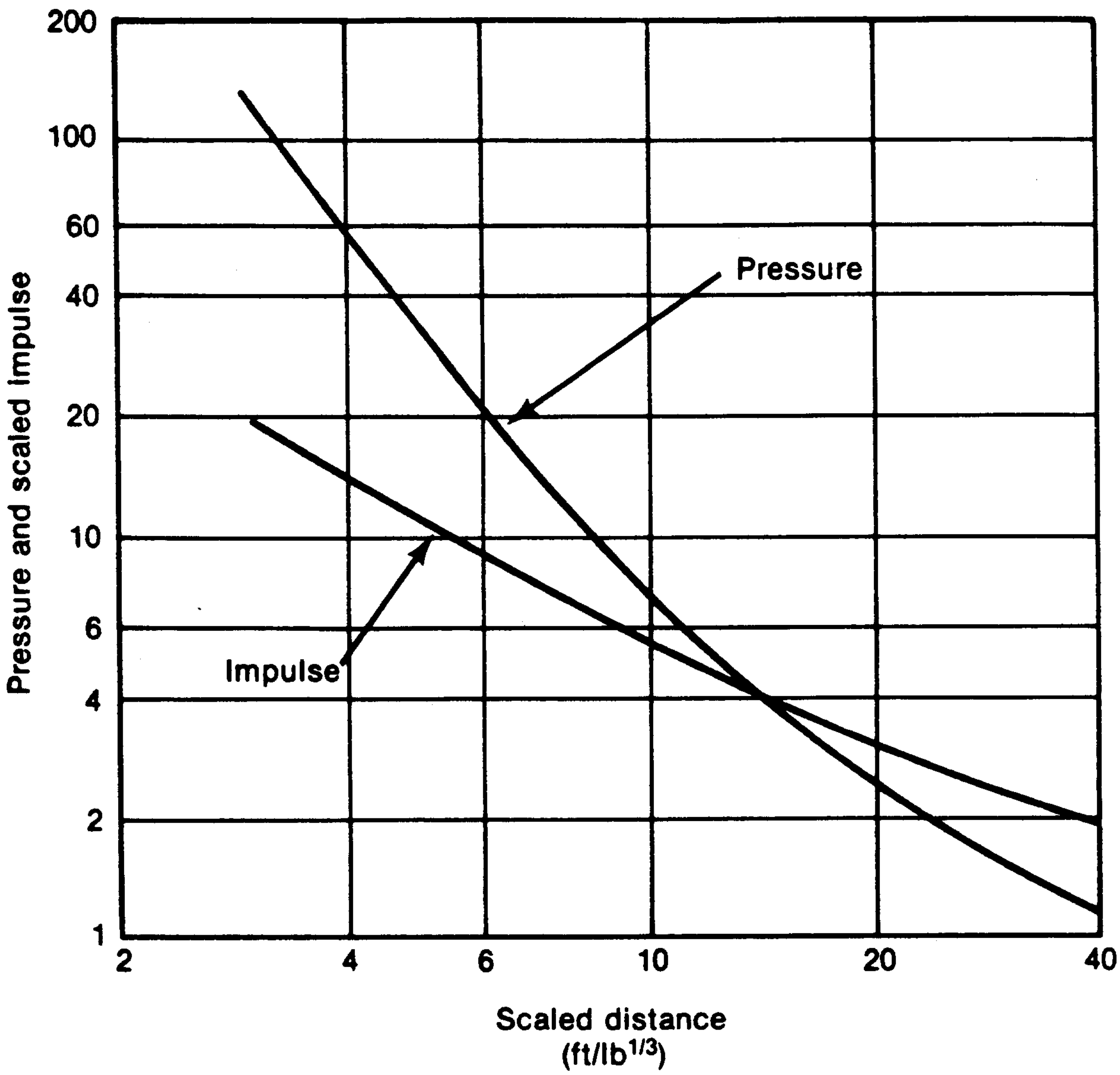


Figure 127. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for N5 Propellant in Charging buckets.

Table 81. Summary of Results for Hemispherical Surface Bursts, Peak Pressure and Scaled Positive Impulse for N5 Propellant with 10% Moistue in Conveyor Belt Configuration.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	80.14	552.59	12.40	111.28	22.000	8.727	1.94	13.34	2.78	24.93
4.000	1.587	39.07	269.37	9.99	89.66	23.000	9.124	1.84	12.70	2.69	24.11
5.000	1.983	23.34	160.90	8.45	75.83	24.000	9.521	1.76	12.12	2.60	23.35
6.000	2.380	15.74	108.53	7.37	66.13	25.000	9.917	1.68	11.61	2.52	22.65
7.000	2.777	11.50	79.30	6.56	58.90	26.000	10.314	1.62	11.15	2.45	21.99
8.000	3.174	8.89	61.29	5.94	53.28	27.000	10.711	1.56	10.74	2.38	21.37
9.000	3.570	7.16	49.37	5.43	48.77	28.000	11.108	1.50	10.37	2.32	20.80
10.000	3.967	5.95	41.03	5.02	45.06	29.000	11.504	1.46	10.03	2.26	20.26
11.000	4.364	5.04	34.96	4.67	41.95	30.000	11.901	1.41	9.73	2.20	19.75
12.000	4.760	4.41	30.38	4.38	39.29	31.000	12.298	1.37	9.44	2.15	19.27
13.000	5.157	3.89	26.83	4.12	37.00	32.000	12.694	1.33	9.19	2.10	18.81
14.000	5.554	3.48	24.02	3.90	35.00	33.000	13.091	1.30	8.95	2.05	18.38
15.000	5.950	3.15	21.75	3.70	33.23	34.000	13.488	1.27	8.73	2.00	17.98
16.000	6.347	2.88	19.88	3.53	31.66	35.000	13.884	1.24	8.53	1.96	17.59
17.000	6.744	2.66	18.32	3.37	30.25	36.000	14.281	1.21	8.35	1.92	17.22
18.000	7.141	2.47	17.00	3.23	28.98	37.000	14.678	1.19	8.17	1.88	16.87
19.000	7.537	2.30	15.88	3.10	27.83	38.000	15.075	1.16	8.01	1.84	16.54
20.000	7.934	2.16	14.92	2.98	26.78	39.000	15.471	1.14	7.87	1.81	16.22
21.000	8.331	2.04	14.08	2.88	25.81	40.000	15.868	1.12	7.73	1.77	15.91

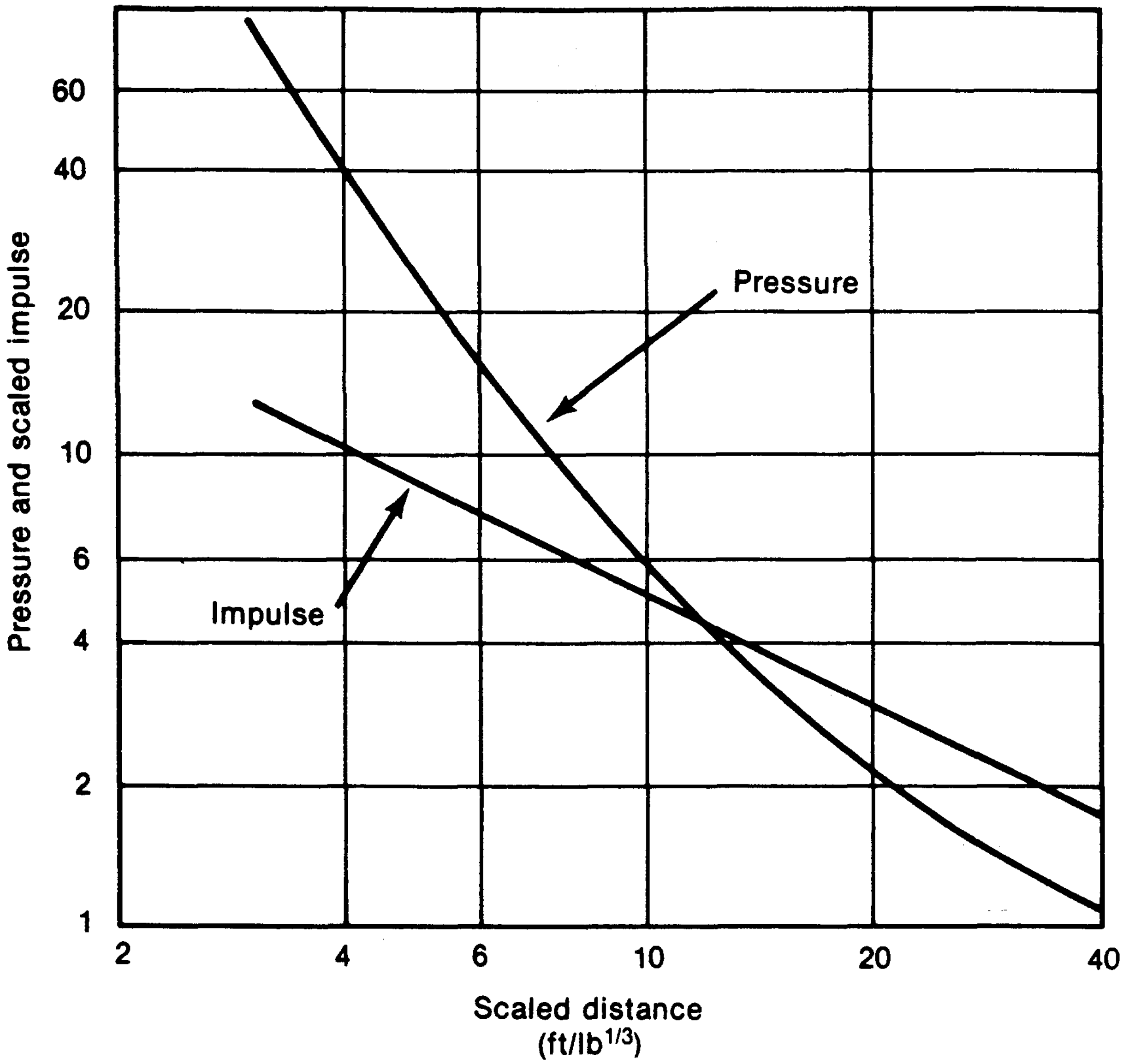


Figure 128. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for N5 Propellant with 10% Moisture in Conveyor Belt Configuration.

Table 82. **Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for 2.75 Inch Rocket Grain MK 43-1.**

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	122.57	845.09	12.80	114.91	22.000	8.727	2.92	20.13	3.12	28.02
4.000	1.587	69.04	476.03	13.72	123.12	23.000	9.124	2.70	18.64	2.97	26.69
5.000	1.983	44.59	307.43	13.11	117.67	24.000	9.521	2.51	17.32	2.84	25.50
6.000	2.380	31.36	216.20	11.98	107.51	25.000	9.917	2.34	16.14	2.72	24.43
7.000	2.777	23.37	161.13	10.76	96.53	26.000	10.314	2.19	15.09	2.61	23.46
8.000	3.174	18.16	125.23	9.61	86.24	27.000	10.711	2.05	14.15	2.52	22.59
9.000	3.570	14.57	100.48	8.59	77.11	28.000	11.108	1.93	13.30	2.43	21.81
10.000	3.967	11.99	82.65	7.71	69.20	29.000	11.504	1.82	12.53	2.35	21.09
11.000	4.364	10.06	69.36	6.95	62.41	30.000	11.901	1.72	11.83	2.28	20.45
12.000	4.760	8.58	59.16	6.31	56.60	31.000	12.298	1.62	11.19	2.21	19.95
13.000	5.157	7.42	51.16	5.75	51.62	32.000	12.694	1.54	10.61	2.15	19.32
14.000	5.554	6.49	44.76	5.28	47.34	33.000	13.091	1.46	10.07	2.10	18.82
15.000	5.950	5.74	39.55	4.86	43.65	34.000	13.488	1.39	9.58	2.05	18.38
16.000	6.347	5.11	35.24	4.51	40.45	35.000	13.844	1.32	9.13	2.00	17.97
17.000	6.744	4.59	31.64	4.20	37.66	36.000	14.281	1.26	8.17	1.96	17.59
18.000	7.141	4.15	28.60	3.92	35.22	37.000	14.678	1.21	8.32	1.92	17.25
19.000	7.537	3.77	26.01	3.69	33.08	38.000	15.075	1.15	7.96	1.89	16.93
20.000	7.934	3.45	23.77	3.47	31.18	39.000	15.471	1.11	7.62	1.85	16.64
21.000	8.331	3.17	21.83	3.29	29.51	40.000	15.868	1.06	7.31	1.83	16.38

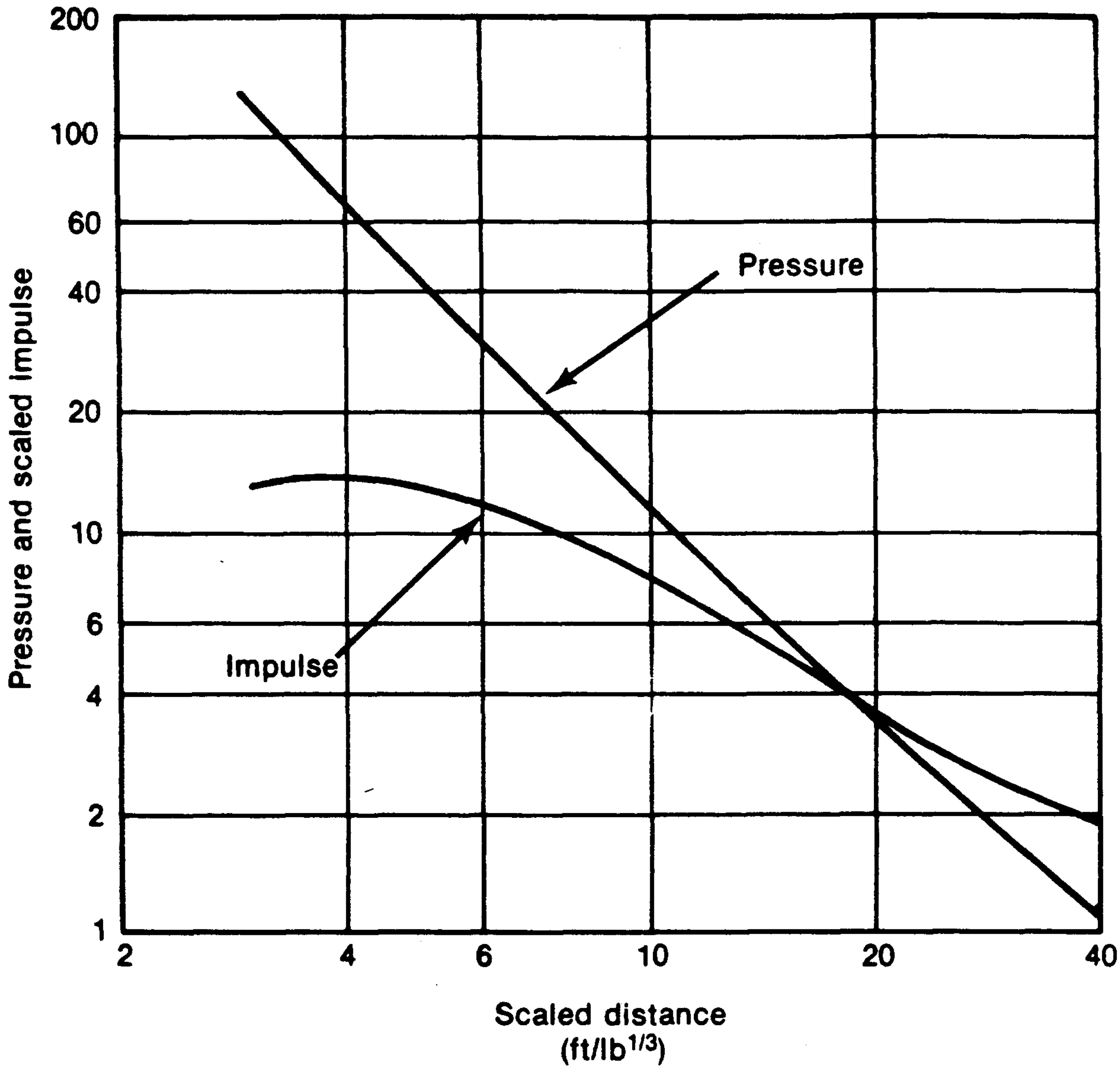


Figure 129. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for 2.75 In Rocket Grain MK 43-1.

OBJECTIVE

The objective of this was to determine the maximum output in terms of peak overpressure and scaled positive impulse from the detonation of a double-base propellant, Ball Powder WC844, and compare the measured values to known characteristics of hemispherical TNT sufrace bursts to determine TNT equivalency.

MATERIALS

The test material was a double-base propellant, Ball Powder, Type WC844, 5.56 mm Ball, DAAA-25-70-C-0613, Army lot 46705, Small Lot 50, manufactured date C-5-71 by Olin Corporation, St. Marks, Flordia. It was received in 45.4 kg (100 lb) quantities in cylindrical shipping containers.

TEST SETUP

Airblast output was evaluated for masses and configurations of Ball Powder WC844 representative of a dryer bed and two charge weights in standard shipping containers. Physical characteristics of the test charges are as folows:

(1) Cylindrical fiberboard containers with 22.7 and 45.4 kg (50 and 100 lb). The length to diameter ratio was 1.6:1.

(2) An orthorhombic fixture constructed from plywood representing a dryer bed with 36.3 and 72.6 kg (80 and 160 lb). The length to diameter ratio was 0.1:1.

The test charges were initiated with a conically shaped Composition C4 booster and a J2 engineers' special blasting cap.

INSTRUMENTATION

Twelve side-on pressure transducers were flush mounted to the ground surface in two sand-filled runways in a 90-degree array. Scaled distances ranged from 1.19 to 15.87 $m/kg^{1/3}$ (3.0, to 40.0 $ft/lb^{1/3}$) and held constant throughout the experiments.

RESULTS

The combined results of the all of the cylindrical tests are given in Table 83 and Figure 130. The orthorhombic dryer bed test results are given in Table 84 and Figure 131. Individual results are given in the orginal test report.

DISCUSSION

Peak pressure values for the combined results of the cylindrical tests with a L/D ratio of 1.6:1 were greater than expected at all scaled distances of the experiment. The pressure values were 2461, 1060, 424, 106, 30, and 10.28 kPa (356.96, 153.77, 61.43, 15.30, 4.37, and 1.49 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0 and, 40.0 $ft/lb^{1/3}$), respectively. These pressures equate to 3.8, 3.1, 2.0, 1.5, 1.5, and 1.7 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values for the combined cylindrical tests were greater than expected at scale distances of 1.19, 1.59, 2.14, and 7.14 $m/kg^{1/3}$ (3.0, 4.0, 5.4, and 18.0 $ft/lb^{1/3}$) and less than expected at scaled distances of 3.57 and 15.87 $m/kg^{1/3}$ (9.0 and 40.0 $ft/lb^{1/3}$). The combined scaled positive impulse values were 264, 175, 119,70, 39, and 16.4 kPa-$ms/kg^{1/3}$ (29.43, 19.50, 13.31, 7.79, 4.35, and 1.83 psi-$ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 2.3, 1.3, 1.2, 1.0, 1.1, and 0.9 times equal amounts of TNT at the same scaled distances, respectively.

Peak pressures for the orthorhomic dryer bed configuration were greater than expected at scaled distances of 1.19, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$) and less than expected at scaled distances of 1.59 and 2.14 $m/kg^{1/3}$ (4.0 and 5.4 $ft/lb^{1/3}$). The pressure values were 971, 360, 184, 85, 31, and 12.43 kPa (140.90, 52.20, 26.69, 12.38, 4.55, and 1.80 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 1.1, 0.7, 0.5, 1.0, 1.6, and 2.6 times equal amounts of TNT at the same scaled distances, respectively. The orthorhombic scaled positive impulse values were less than expected at scaled distances equal to or less than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$) and greater than expected at scaled distances equal to or greater than 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$). The scaled positive impulse values were 130, 100, 80, 60, 43, and 22.64 kPa-$ms/kg^{1/3}$ (14.47, 11.14, 8.93, 6.69, 4.78, and 2.52 psi-$ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 0.7, 0.4, 0.7, 0.7, 1.2, and 1.5 times equal anounts of TNT at the same scaled distances, respectively.

The higher pressure and impulse values at the far-field scaled distances are due in part to the dryer bed configuration. All other materials tested in this configuration followed the same general trend.

CONCLUSIONS

(1) Peak pressure values were greater than equal amounts of TNT at all scaled distances of the experiment for cylindrical charges with a L/D=1.6:1.

(2) The high peak pressures are attributed to the test configuration.

(3) Scaled positive impulse values varied as a function of the scaled distance but they were generally greater than expected at the near-field scaled distances.

(4) Peak pressure and scaled positive impulse varied as a function

of the scaled distance and were generally higher at the far-field scaled distances. This same trend was noted by other explosives and propellants tested in the dryer bed test configuration.

(5) Peak pressure and scaled positive impulse varied as a function of scaled distance and were dependent upon the geometry tested.

(6) To within experimental limits of the instrumentation and the explosive material, pressure and impulse scaled as a cube root function of the charge weights when the geometries were similar.

Table 83. Summary of Results of Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse Values for WC844 Ball Powder in Cylindrical Configuration, L/D=1.6:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	356.96	2461.23	29.43	264.08	22.000	8.727	3.39	23.37	3.66	32.83
4.000	1.587	153.77	1060.27	19.50	175.00	23.000	9.124	3.21	22.16	3.51	31.51
5.000	1.983	77.55	534.70	14.61	131.11	24.000	9.521	3.05	21.05	3.37	30.27
6.000	2.380	44.96	310.00	11.79	105.76	25.000	9.917	2.91	20.05	3.24	29.09
7.000	2.777	29.07	200.41	9.97	89.49	26.000	10.314	2.77	19.12	3.12	27.97
8.000	3.174	20.43	140.83	8.72	78.22	27.000	10.711	2.65	18.26	3.00	26.90
9.000	3.570	15.30	105.50	7.79	69.95	28.000	11.108	2.53	17.46	2.88	25.88
10.000	3.967	12.04	83.05	7.09	63.60	29.000	11.504	2.42	16.70	2.78	24.91
11.000	4.364	9.86	67.96	6.53	58.56	30.000	11.901	2.32	15.98	2.67	23.98
12.000	4.760	8.32	57.34	6.06	54.42	31.000	12.298	2.22	15.30	2.57	23.08
13.000	5.157	7.19	49.57	5.68	50.94	32.000	12.694	2.12	14.65	2.48	22.22
14.000	5.554	6.34	43.71	5.34	47.95	33.000	13.091	2.03	14.03	2.38	21.39
15.000	5.950	5.68	39.15	5.05	45.34	34.000	13.488	1.95	13.43	2.30	20.60
16.000	6.347	5.15	35.52	4.79	43.03	35.000	13.884	1.86	12.86	2.21	19.83
17.000	6.744	4.72	32.57	4.56	40.95	36.000	14.281	1.78	12.31	2.13	19.09
18.000	7.141	4.37	30.13	4.35	39.05	37.000	14.678	1.71	11.77	2.05	18.38
19.000	7.537	4.07	28.06	4.16	37.32	38.000	15.075	1.63	11.26	1.97	17.70
20.000	7.934	3.81	26.28	3.98	35.72	39.000	15.471	1.56	10.76	1.90	17.04
21.000	8.331	3.59	24.74	3.81	34.22	40.000	15.868	1.49	10.28	1.83	16.41

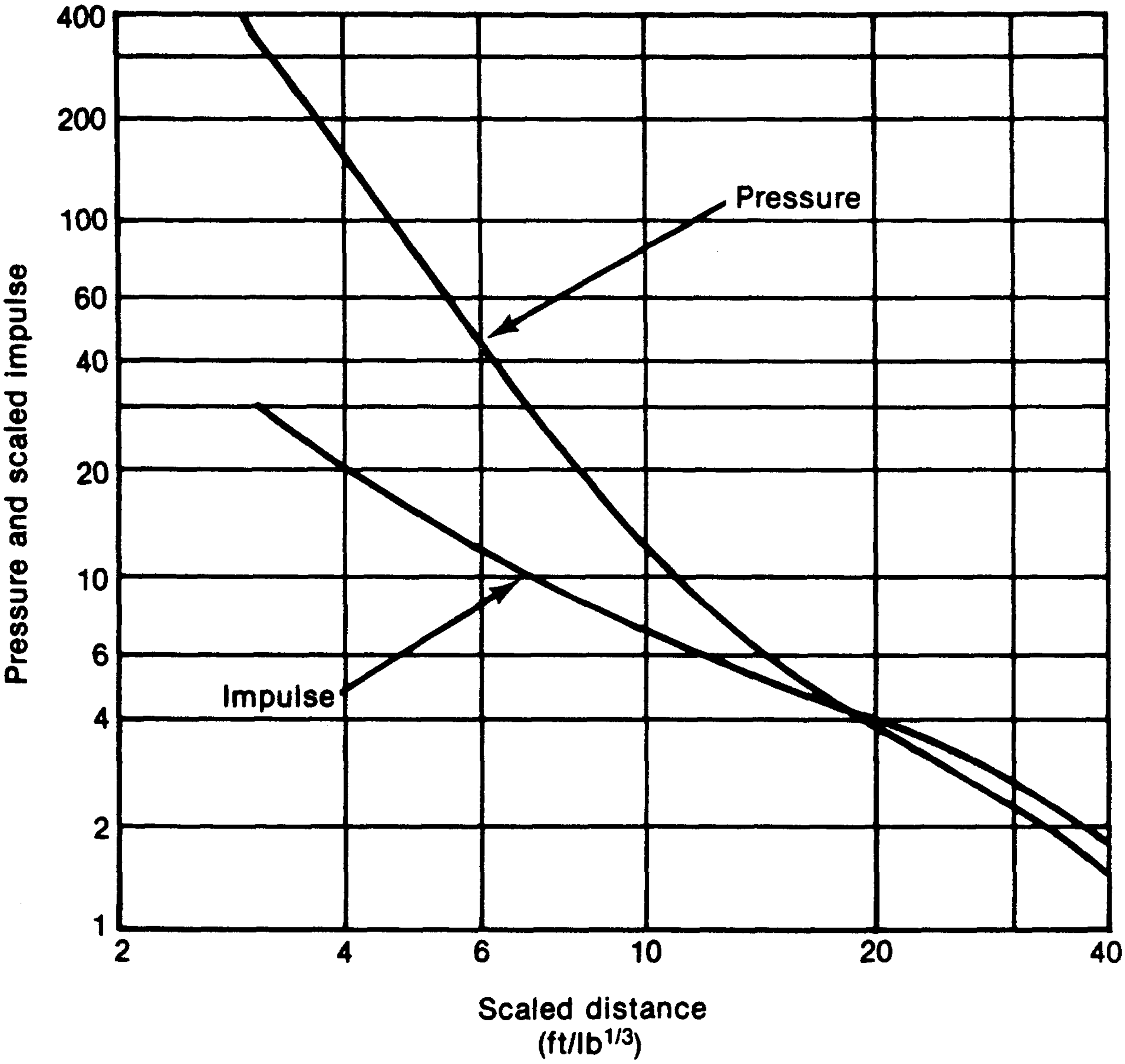


Figure 130. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for WC844 Ball Powder in Cylindrical Configuration, L/D=1.6:1.

Table 34. Summary of Results of Hemispherical Surface Bursts, Peak Pressure and Scaled Positive Impulse Values for WC844 Ball Powder in Orthorhombic Configuration, L/D=0.1:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	140.90	971.47	14.47	129.89	22.000	8.727	3.35	23.13	4.25	38.13
4.000	1.587	52.20	359.91	11.14	99.99	23.000	9.124	3.14	21.66	4.13	37.04
5.000	1.983	30.93	213.23	9.41	84.43	24.000	9.521	2.96	20.38	4.01	35.99
6.000	2.380	22.25	153.44	8.35	74.92	25.000	9.917	2.79	19.25	3.90	34.97
7.000	2.777	17.56	121.07	7.63	68.47	26.000	10.314	2.65	18.25	3.79	33.98
8.000	3.174	14.54	100.27	7.10	63.74	27.000	10.711	2.52	17.37	3.68	33.02
9.000	3.570	12.38	85.38	6.69	60.08	28.000	11.108	2.41	16.60	3.57	32.08
10.000	3.967	10.73	73.98	6.36	57.10	29.000	11.504	2.31	15.92	3.47	31.17
11.000	4.364	9.41	64.88	6.08	54.59	30.000	11.901	2.22	15.32	3.37	30.28
12.000	4.760	8.33	57.42	5.84	52.42	31.000	12.298	2.15	14.79	3.28	29.42
13.000	5.157	7.42	51.18	5.63	50.49	32.000	12.694	2.08	14.33	3.19	28.59
14.000	5.554	6.66	45.91	5.43	48.74	33.000	13.091	2.02	13.93	3.09	27.77
15.000	5.950	6.01	41.42	5.25	47.14	34.000	13.488	1.97	13.59	3.01	26.98
16.000	6.347	5.45	37.57	5.09	45.64	35.000	13.884	1.93	13.29	2.92	26.20
17.000	6.744	4.97	34.25	4.93	44.24	36.000	14.281	1.89	13.04	2.84	25.45
18.000	7.141	4.55	31.37	4.78	42.91	37.000	14.678	1.86	12.83	2.75	24.72
19.000	7.537	4.19	28.87	4.64	41.64	38.000	15.075	1.84	12.66	2.68	24.01
20.000	7.934	3.87	26.70	4.50	40.42	39.000	15.471	1.82	12.53	2.60	23.32
21.000	8.331	3.60	24.79	4.37	39.26	40.000	15.868	1.80	12.43	2.52	22.64

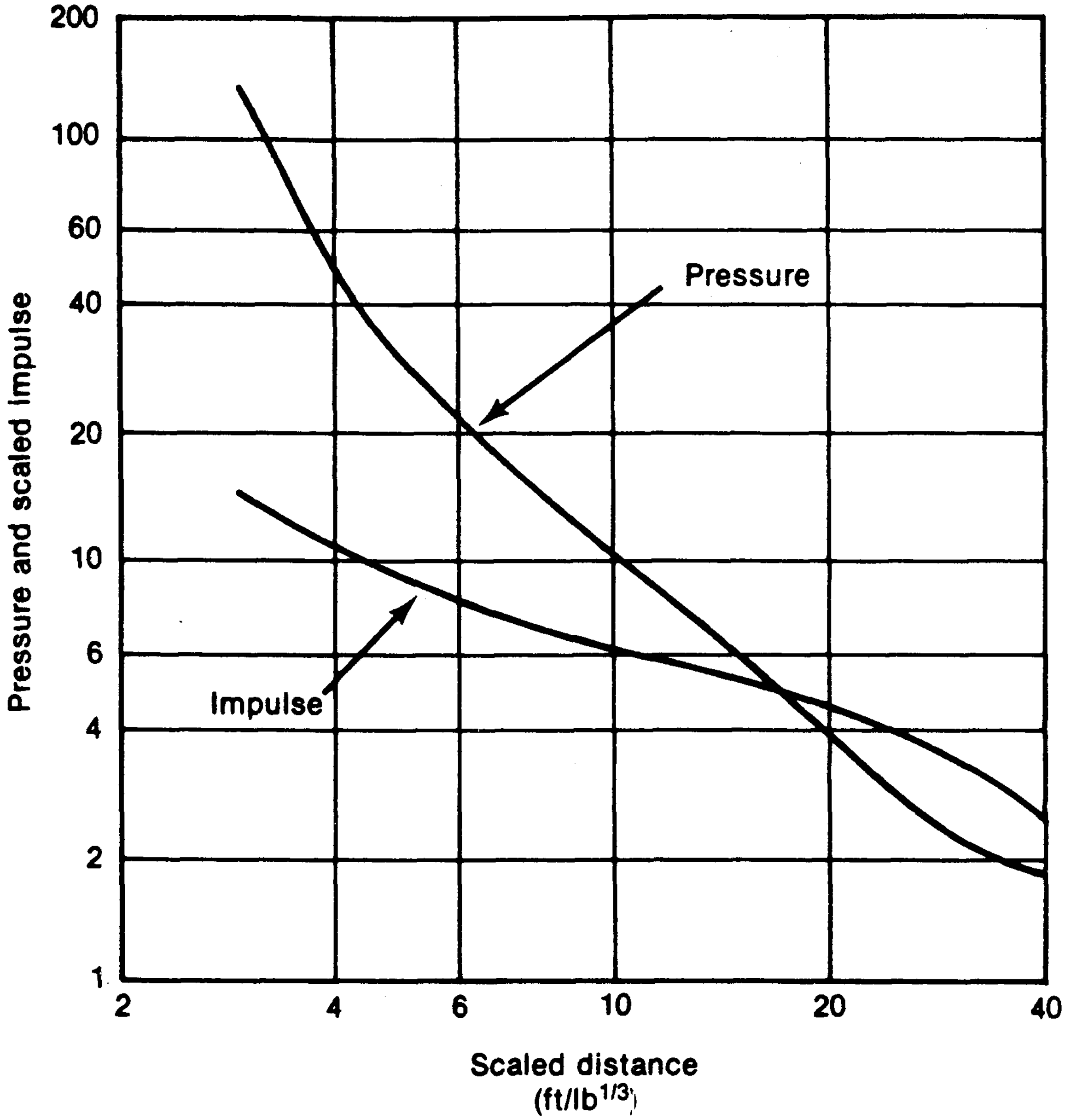


Figure 131. Peak Pressure and Scaled Positive Impulse Versus Scale Distance for WC844 Ball Powder in Orthorhombic Configuration, L/D=0.1:1.

XM37 PROPELLANT, RAP 549
FORWAD AND AFT GRAIN[38]

OBJECTIVE

The objective of this study was to determine the maximum output from the detonation of XM37 propellant in terms of peak airblast overpressure and positive impulse. The measured output was compared to standard hemispherical TNT data to determine the TNT equivalency.

MATERIALS

The XM37 propellant consists of nitrocellulose 12.6%, nitroglycerine, 2 NDPA, triacetene (TA), lead salts, lead salicylate, and wax in percentages of 50/36.2/1.0/9.7/1.5/1.5/0.1, respectively. The propellant met MIL-P-63201 specifications.

TEST SETUP

Airblast output was evaluated for weights and configurations representing a single forward and aft grain, a simulated extruded billet for forward and aft grains, and the Ro Con shipping drum for forward and aft grains. Physical characteristics are as folows:

(1) A single forward grain with a charge weight of 1.9 kg (4.2 lb), a simulated extruded billet forward grain with a charge weight of 22.97 kg (50.64 lb), and the forward grain was tested in the Ro Con shipping drum at a 22.97 kg (50.64 lb) charge weight.

(2) A single aft grain with a charge weight of 1.02 kg (2.24 lb), a simulated extruded billet aft grain with a charge weight of 16.26 kg (35.84 lb) and the aft grain in the Ro Con shipping drum with a charge weight of 12.19 kg (26.88 lb) was tested.

INSTRUMENTATION

Twelve side-on pressrue transducers were mounted flush to the ground surface in each of two sand-filled 90-degree arrays. Distances from the charge to the transducers correspond to scaled distances ranging from 1.98 to 15.87 m/kg$^{1/3}$ (5.0 to 40.0 ft/lb$^{1/3}$). The scaled distances remained constant throughout the experiments.

RESULTS

Peak pressure and scaled positive impulse values for the Single Forward Grain are given in Table 85 and Figure 132. The results of the Simulated Extruded Billets for the Forward Grain are given in Table 86 and Figure 133. The results of the Ro Con Shipping Container for the Forward Grain are given in Table 87 and Figure 134. The results of the Aft Single Grain tests are given in Table 88 and Figure 135. The Aft Simulated Extruded Billet results are given in Table 89 and Figure 136. The results of the Aft Grain in the Ro Con Shipping Drum are given in Table 90 and Figure 137.

DISCUSSION

Pressure values for the 1.91 kg (4.22 lb) Single Forward Grain were greater than expected at all scaled distances of the experiment. The pressure values were 1085, 637, 345, 114, 27.44, and 8.74 kPa (145.4, 92.45, 50.06, 16.55, 3.98, and 1.27 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 1.3, 1.7, 2.3, 1.4, 1.3, and 1.1 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were equal to or greater than expected at all scaled distances of the experiment. The scaled positive impulse values were 272, 180, 124, 71, 38.2, and 19.16 kPa-$ms/kg^{1/3}$ (30.38, 20.1, 13.78, 7.97, 4.25, and 2.14 psi-$ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 2.1, 1.7, 1.3, 1.0, 1.0, and 1.2 times equal amounts of TNT a the same scaled distances, respectively.

The pressure values for the 22.97 kg (54.64 lb) Simulated Forward Extruded Billet were greater than expected at all scaled distances of the experiment. The pressure values were 1356, 805, 444, 150, 35.31, and 9.15 kPa (196.62, 116.82, 64.35, 21.79, 5.11, and 1.33 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0 5.4 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 1.7, 2.3, 2.7, 2.4, 2.0, and 1.2 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were greater than expected at all scaled distances of the experiment. The scaled positive impulse values were 280, 188, 131, 76, 40.4, and 19.63 kPa-$ms/kg^{1/3}$ (31.24, 21.00, 14.54, 8.47, 4.50, and 2.19 psi-$ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 2.1, 1.8, 1.5, 1.2, 1.1, and 1.2 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the 22.97 kg (50.65 lb0 Ro Con Drum (Forward Grain) were greater than expected at all scaled distances of the experiment. The pressure values were 1615, 843, 414, 122, 27.69, and 9.37 kPa (234.21, 122.19, 60.04, 17.77, 4.02, and 1.30 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 1.8, 2.5, 2.8, 1.8, 1.4, and 1.2 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were greater than expected at all scaled distances of the experiment. The scaled positive impulse values were 299, 206, 142, 79, 38.25, and 18.09 kPa-$ms/kg^{1/3}$ (33.31, 22.94, 15.84, 8.80, 4.26, and 2.02 psi-$ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 2.2, 2.5, 2.5, 1,2, 1.0, and 1.1 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the Single Aft Grain were greater than expected at all scaled diatances of the experiment. The pressure values were 1065, 552, 285, 100, 29.57, and 10.24 kPa (154.43, 80.02, 41.41, 14.57, 4.29, and 1.48 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 1.2, 1.4, 1.5, 1.4, 1.5, and 1.6 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were greater than expected at all scaled distances of the experiment. The scaled positive impulse values were 272, 160, 106, 76, 53 and 20.42 kPa-$ms/kg^{1/3}$ (30.27, 17.81, 12.22, 8.45, 5.92, and 2.28 psi-$ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 1.9, 1.8, 1.1, 1.2, 1.7, and 1.3 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the 16.26 kg (35.84 lb) Simulated Aft Extruded Billet were greater than expected at all scaled distances of the experiment. The pressure values were 1575, 802, 408, 139, 36.99, and 10.09 kPa (228.44, 116.39, 59.24, 20.10, 5.36, and 1.46 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 2.0, 2.5, 2.3, 2.1, 2.2, and 1.6 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were greater than expected at all scaled distances of the experiment. The scaled positive impulse values were 258, 183, 133, 81, 44.1, and 21.76 kPa-$ms/kg^{1/3}$ (28.7, 20.41, 14.77, 9.02, 4.91, and 2.43 psi-$ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 1.9, 1.5, 1.6, 1.3, 1.3, and 1.4 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the 12.19 kg (26.88 lb) Ro Con Shipping Drum (Aft Grain) were greater than expected at all scaled distances of the experiment. The pressure values were 1591, 131, 449, 123, 24.84, and 10.01 kPa (230.68, 30.78, 65.18, 17.86, 3.60, and 1.45 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 1.7, 2.7, 3.4, 1.8, 1.1, and 1.6 times equal amounts of TNT at the same scaled distances respectively. The scaled positive impulse values were greater than expectd at all scaled distances of the experiment. The scaled positive impulse values were 332, 158, 94, 60, 44.87, and 19.09 kPa-$ms/lb^{1/3}$ (36.99, 17.55, 10.48, 6.65, 5.00, and 2.13 psi-$ms/^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 2.4, 2.6, 2.9, 1.0, 1.3, and 1.2 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) The blast output from the XM37 RAP propellant is dependent upon the configuration from which it detonates.

(2) TNT equivalency values were determined for XM37 RAP propellant in three different configurations for both the forward and aft grains. The test results indicate that the measured values for blast overpressure and positive impulse were greater than those expected for equal amounts of TNT at the same scaled distances respectively.

(3) To within experimental limits, the blast over pressure and impulse follow the scaling laws.

Table 85. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for XM37 RAP Propellant Single Forward Grain, L/D=0.76:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	157.40	1085.28	30.28	271.77	22.000	8.727	2.79	19.24	3.59	32.20
4.000	1.587	92.45	637.44	20.10	180.35	23.000	9.124	2.59	17.63	3.46	31.01
5.000	1.983	58.84	405.69	15.12	135.65	24.000	9.521	2.42	16.70	3.33	29.91
6.000	2.380	39.99	275.72	12.20	109.52	25.000	9.917	2.27	15.66	3.22	28.89
7.000	2.777	28.64	197.47	10.30	92.44	26.000	10.314	2.14	14.76	3.11	27.94
8.000	3.174	21.40	147.53	8.96	80.42	27.000	10.711	2.02	13.96	3.01	27.05
9.000	3.570	16.55	114.09	7.97	71.48	28.000	11.108	1.92	13.25	2.92	26.22
10.000	3.967	13.17	90.78	7.19	64.56	29.000	11.504	1.85	12.75	2.85	25.60
11.000	4.364	10.73	73.98	6.58	59.03	30.000	11.901	1.75	12.06	2.75	24.71
12.000	4.760	8.92	61.53	6.07	54.49	31.000	12.298	1.68	11.56	2.68	24.02
13.000	5.157	7.55	52.08	5.65	50.70	32.000	12.694	1.61	11.20	2.62	23.49
14.000	5.554	6.49	44.75	5.29	47.47	33.00	13.091	1.55	10.70	2.53	22.74
15.000	5.950	5.65	38.97	4.98	44.68	34.000	13.488	1.50	10.34	2.47	22.16
16.000	6.347	4.98	34.33	4.71	42.25	35.000	13.884	1.45	10.00	2.41	21.60
17.000	6.744	4.43	30.57	4.47	40.10	36.000	14.281	1.41	9.70	2.35	21.06
18.000	7.141	3.98	27.44	4.25	38.18	37.000	14.678	1.37	9.43	2.29	20.55
19.000	7.537	3.60	24.85	4.06	36.46	38.000	15.075	1.33	9.18	2.24	20.07
20.000	7.934	3.29	22.67	3.89	34.91	39.000	15.471	1.30	8.95	2.18	19.60
21.000	8.331	3.02	20.82	3.73	33.49	40.000	15.868	1.27	8.74	2.14	19.16

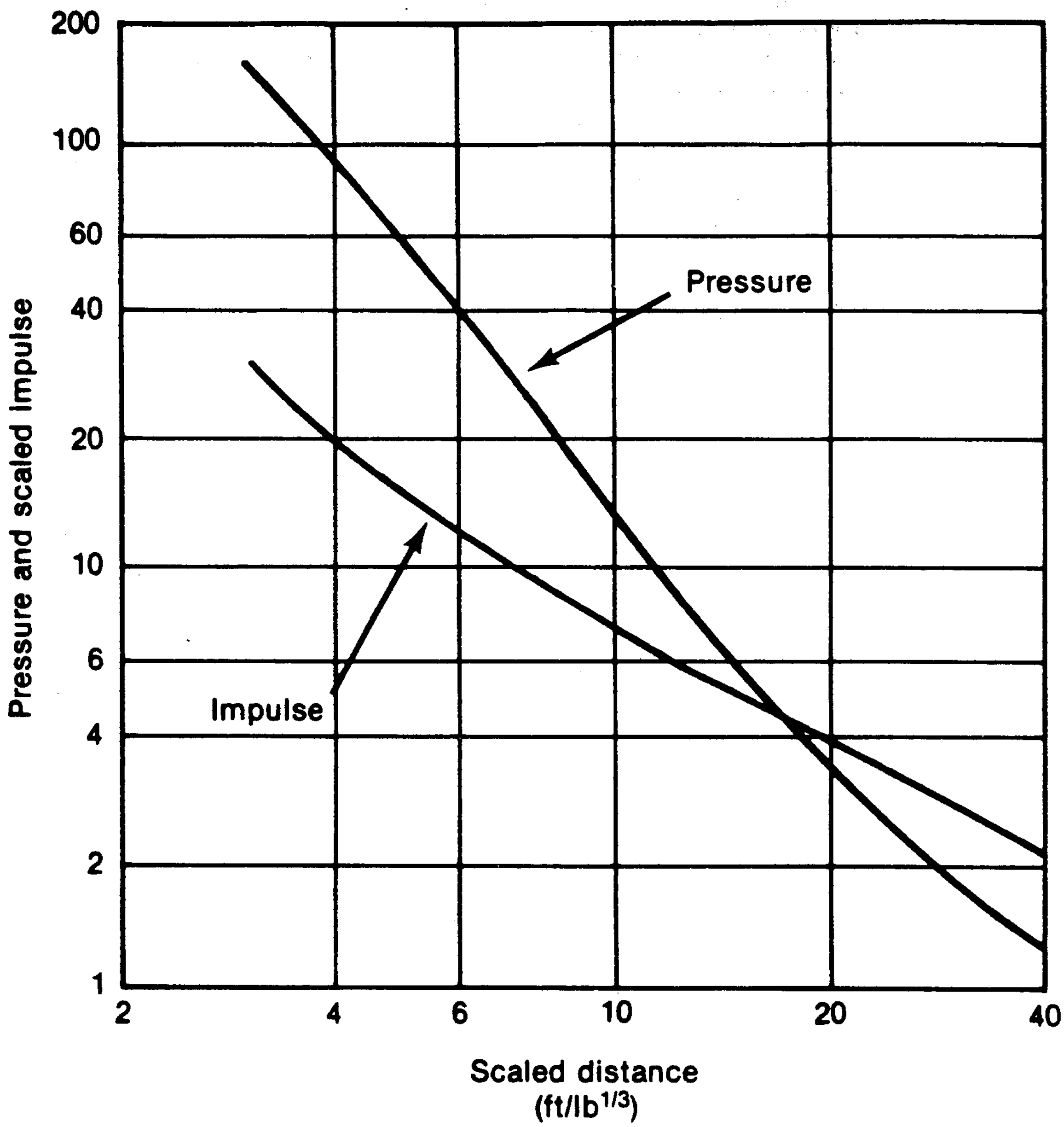


Figure 132. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for XM37 RAP Propellant Single Forward Grain, L/D=0.76:1.

Table 86. **Summary of Results for Hemispherical Surface Bursts. Peak Pressure, and Scaled Positive Impulse for XM37 RAP Propellant Forward Grain Simulated Extruded Billet, L/D=9.09:1.**

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	196.62	1355.73	31.24	780.33	22.000	8.727	3.48	23.97	3.77	33.86
4.000	1.587	116.82	805.46	21.00	188.42	23.000	9.124	3.20	22.09	3.63	32.56
5.000	1.983	75.29	519.12	15.91	142.81	24.000	9.521	2.97	20.45	3.49	31.36
6.000	2.380	51.72	356.60	12.91	115.84	25.000	9.917	2.76	19.02	3.37	30.25
7.000	2.777	37.35	257.52	10.93	98.06	26.000	10.314	2.58	17.76	3.25	29.21
8.000	3.174	28.07	193.53	9.52	85.46	27.000	10.711	2.41	16.65	3.15	28.24
9.000	3.570	21.79	150.22	8.47	76.03	28.000	11.108	2.27	15.66	3.05	27.34
10.000	3.967	17.37	119.75	7.65	68.69	29.000	11.504	2.14	14.79	2.95	26.48
11.000	4.364	14.16	97.62	7.00	62.86	30.000	11.901	2.03	13.98	2.86	25.68
12.000	4.760	11.76	81.11	6.46	57.95	31.000	12.298	1.92	13.27	2.78	24.93
13.000	5.157	9.93	68.49	6.000	53.89	32.000	12.694	1.83	12.62	2.70	24.21
14.000	5.554	8.51	58.66	5.62	50.41	33.000	13.091	1.75	12.04	2.62	23.54
15.000	5.950	7.38	50.86	5.28	47.41	34.000	13.488	1.67	11.51	2.55	22.89
16.000	6.347	6.47	44.58	4.99	44.78	35.000	13.884	1.60	11.03	2.48	22.28
17.000	6.744	5.72	39.45	4.73	42.45	36.000	14.281	1.54	10.59	2.42	21.70
18.000	7.141	5.11	35.21	4.50	40.37	37.000	14.678	1.48	10.18	2.36	21.15
19.000	7.537	4.59	31.68	4.29	38.56	38.000	15.075	1.42	9.81	2.30	20.62
20.000	7.934	4.16	28.69	4.10	36.81	39.000	15.471	1.37	9.47	2.24	20.11
21.000	8.331	3.79	26.15	3.93	35.27	40.000	15.868	1.33	9.15	2.19	19.63

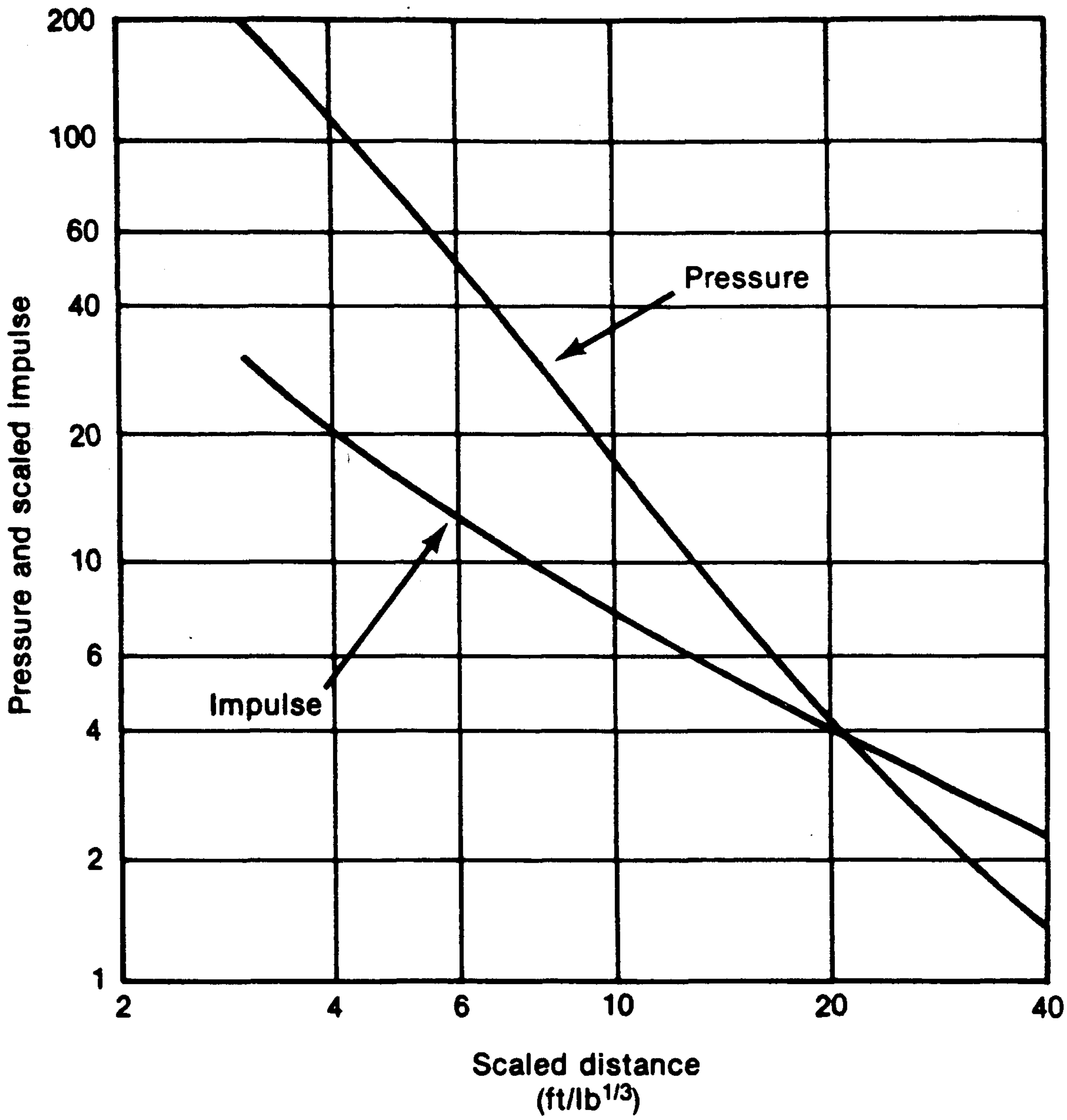


Figure 133. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for XM37 RAP Propellant Forward Grain Simulated Extruded Billet, L/D=0.09:1.

Table 87. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for XM37 RAP Propellant Forward Grain in Ro Con Shipping Container, L/D=1.54:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	234.21	1614.90	33.31	298.92	22.000	8.727	2.81	19.35	3.50	31.44
4.000	1.587	122.19	842.51	22.94	205.85	23.000	9.124	2.61	17.98	3.36	30.13
5.000	1.983	72.18	497.65	17.39	156.06	24.000	9.521	2.44	16.80	3.22	28.93
6.000	2.380	46.63	321.51	13.98	125.42	25.000	9.917	2.29	15.76	3.10	27.83
7.000	2.777	32.21	222.12	11.68	104.86	26.000	10.314	2.16	14.86	2.99	26.82
8.000	3.174	23.44	161.60	10.03	90.02	27.000	10.711	2.04	14.07	2.88	25.89
9.000	3.570	17.77	122.49	8.80	78.95	28.000	11.108	1.94	13.37	2.79	25.03
10.000	3.967	13.92	95.98	7.84	70.35	29.000	11.504	1.85	12.74	2.70	24.22
11.000	4.364	11.21	77.30	7.07	63.49	30.000	11.901	1.77	12.19	2.62	23.48
12.000	4.760	9.24	63.70	6.45	57.89	31.000	12.298	1.70	11.70	2.54	22.78
13.000	5.157	7.76	53.53	5.93	53.23	32.000	12.694	1.63	11.25	2.47	22.13
14.000	5.554	6.63	45.73	5.49	49.30	33.000	13.091	1.57	10.85	2.40	21.51
15.000	5.950	5.75	39.64	5.12	45.94	34.000	13.488	1.52	10.49	2.33	20.94
16.000	6.347	5.05	34.80	4.79	43.03	35.00	13.884	1.47	10.17	2.27	20.39
17.000	6.744	4.48	30.89	4.51	40.49	36.000	14.281	1.43	9.87	2.22	19.88
18.000	7.141	4.02	27.69	4.26	38.25	37.000	14.678	1.39	9.61	2.16	19.40
19.000	7.537	3.63	25.04	4.04	36.26	38.000	15.075	1.36	9.37	2.11	18.94
20.000	7.934	3.31	22.82	3.84	34.48	39.000	15.471	1.33	9.15	2.06	18.51
21.000	8.331	3.04	20.95	3.66	32.89	40.000	15.868	1.30	8.95	2.02	18.09

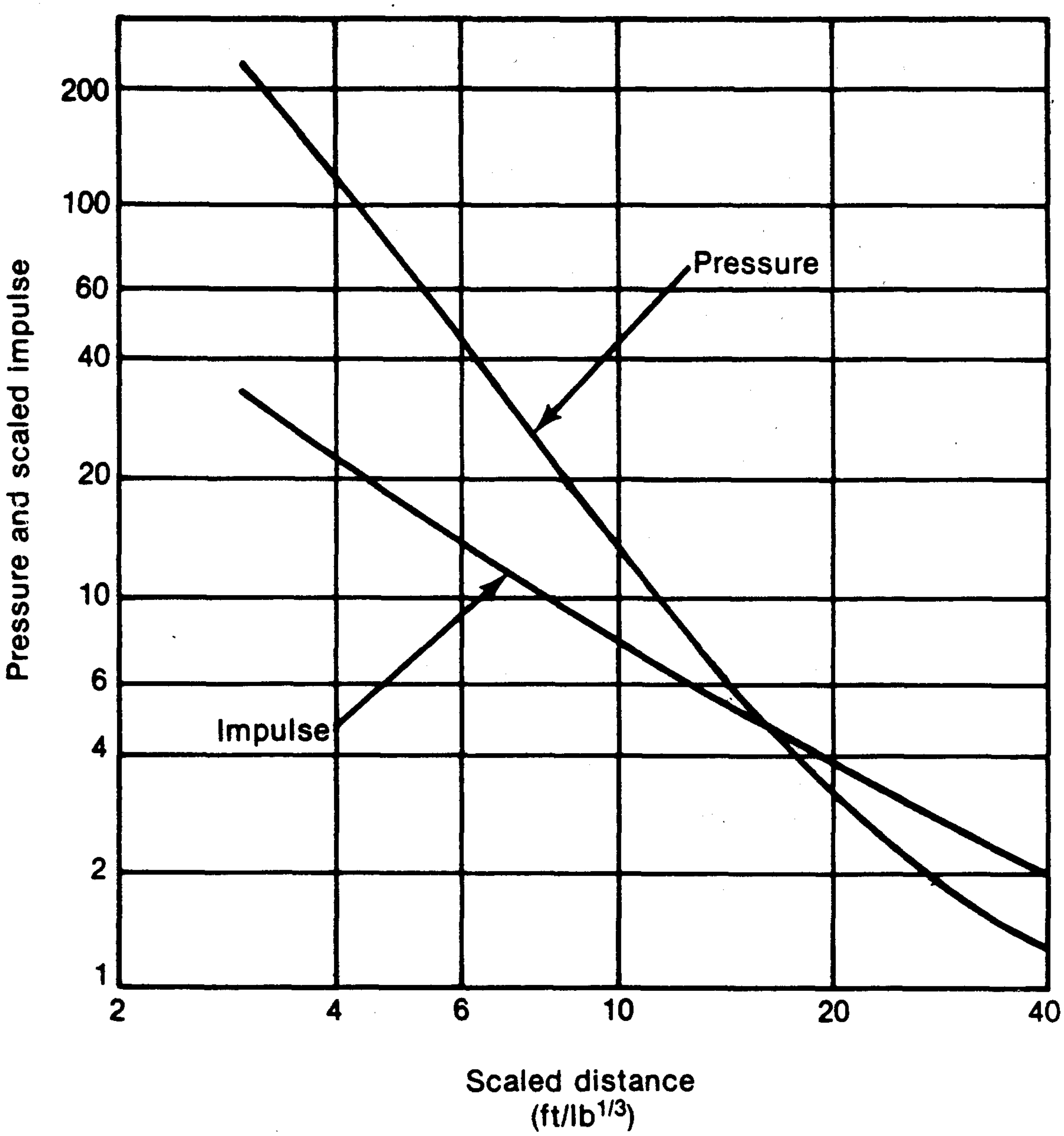


Figure 134. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for XM37 RAP Propellant Forward Grain in Ro Con Shipping Container, L/D=1.54:1.

Table 88. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for XM37 RAP Propellant Single Aft Grain, L/D=0.64:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	154.43	1064.80	30.27	271.60	22.000	8.727	3.16	21.80	5.09	45.71
4.000	1.587	80.02	551.73	17.81	159.81	23.000	9.124	2.96	20.44	4.89	43.93
5.000	1.983	48.89	337.07	13.27	119.07	24.000	9.521	2.79	19.25	4.70	42.19
6.000	2.380	33.10	228.23	11.07	99.38	25.000	9.917	2.64	18.18	4.51	40.48
7.000	2.777	24.04	165.75	9.82	88.13	26.000	10.314	2.50	17.23	4.33	38.82
8.000	3.174	18.36	126.62	9.01	80.90	27.000	10.711	2.38	16.38	4.15	37.21
9.000	3.570	14.57	100.48	8.45	75.79	28.000	11.108	2.26	15.62	3.97	35.63
10.000	3.967	11.91	82.15	8.01	71.96	29.000	11.504	2.16	14.92	3.80	34.11
11.000	4.364	9.97	68.77	7.66	68.74	30.000	11.901	2.07	14.29	3.64	32.63
12.000	4.760	8.51	58.70	7.36	66.02	31.000	12.298	1.99	13.72	3.48	31.19
13.000	5.157	7.38	50.91	7.08	63.57	32.000	12.694	1.91	13.20	3.32	29.81
14.000	5.554	6.49	44.76	6.83	61.32	33.000	13.091	1.84	12.72	3.17	28.47
15.000	5.950	5.77	39.81	6.59	59.18	34.000	13.488	1.78	12.28	3.03	27.18
16.000	6.347	5.19	35.75	6.36	57.12	35.000	13.884	1.72	11.87	2.89	25.94
17.000	6.744	4.70	32.39	6.14	55.12	36.000	14.281	1.67	11.49	2.76	24.74
18.000	7.141	4.29	29.57	5.92	53.16	37.000	14.678	1.62	11.14	2.63	23.59
19.000	7.537	3.94	27.17	5.71	51.25	38.000	15.075	1.57	10.82	2.51	22.49
20.000	7.934	3.64	25.12	5.50	49.37	39.000	15.471	1.53	10.52	2.39	21.43
21.000	8.331	3.39	23.34	5.30	47.52	40.000	15.868	1.48	10.24	2.28	20.42

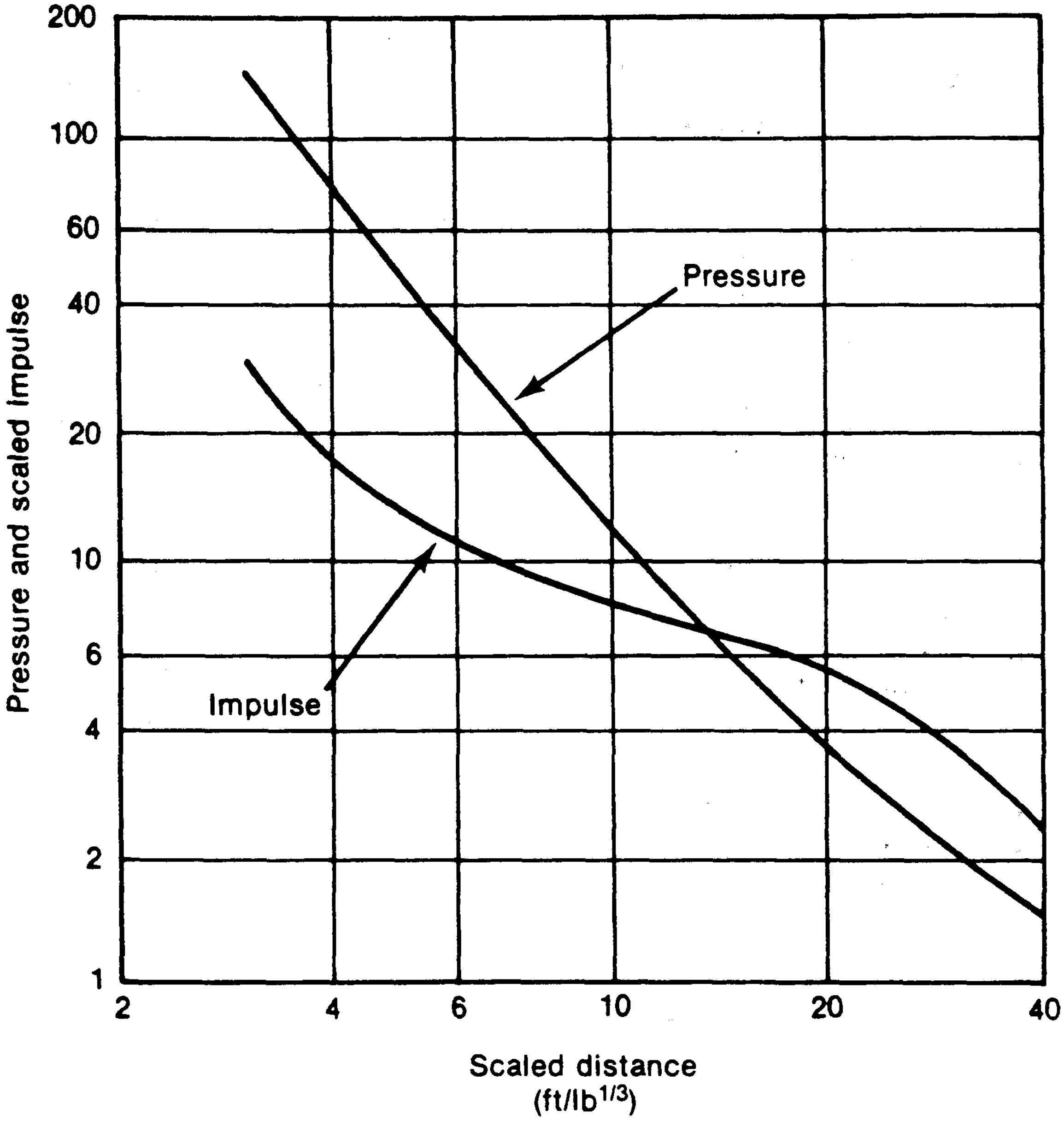


Figure 135. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for XM37 RAP Propellant Single Aft Grain, L/D=0.64:1.

Table 89. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for XM37 RAP Propellant Aft Grain Simulated Billets, L/D=10.22:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	228.44	1575.07	28.70	257.59	22.000	8.727	3.78	26.08	4.14	37.12
4.000	1.587	116.39	802.48	20.41	183.19	23.000	9.124	3.51	24.18	3.98	35.72
5.000	1.983	70.24	484.33	16.01	143.63	24.000	9.521	3.27	22.52	3.84	34.43
6.000	2.380	47.06	324.48	13.27	119.11	25.000	9.917	3.05	21.04	3.70	33.23
7.000	2.777	33.83	233.28	11.41	102.39	26.000	10.314	2.86	19.72	3.58	32.11
8.000	3.174	25.59	176.42	10.05	90.21	27.000	10.711	2.69	18.54	3.46	31.06
9.000	3.570	20.10	138.59	9.02	80.91	28.000	11.108	2.54	17.48	3.35	30.08
10.000	3.967	15.63	107.80	8.05	72.25	29.000	11.504	2.40	16.52	3.25	29.16
11.000	4.364	13.47	92.89	7.53	67.56	30.000	11.901	2.27	15.66	3.15	28.30
12.000	4.760	11.38	78.44	6.97	62.58	31.000	12.298	2.18	15.02	3.08	27.64
13.000	5.257	9.76	67.31	6.50	58.36	32.000	12.694	2.05	14.15	2.99	26.86
14.000	5.554	8.49	58.53	6.10	54.73	33.000	13.091	1.96	13.49	2.89	25.98
15.000	5.950	7.47	51.48	5.75	51.57	34.000	13.488	1.87	12.88	2.82	25.29
16.000	6.347	6.63	45.73	5.44	48.79	35.000	13.884	1.79	12.32	2.74	24.63
17.000	6.744	5.94	40.98	5.16	46.32	36.000	14.281	1.71	11.80	2.67	24.00
18.000	7.141	5.36	36.99	4.91	44.10	37.000	14.678	1.64	11.33	2.61	23.40
19.000	7.537	4.88	33.62	4.69	42.10	38.000	15.075	1.58	10.88	2.54	22.83
20.000	7.934	4.46	30.73	4.49	40.29	39.000	15.471	1.52	10.47	2.48	22.29
21.000	8.331	4.10	28.29	4.31	38.69	40.000	15.868	1.46	10.09	2.43	21.76

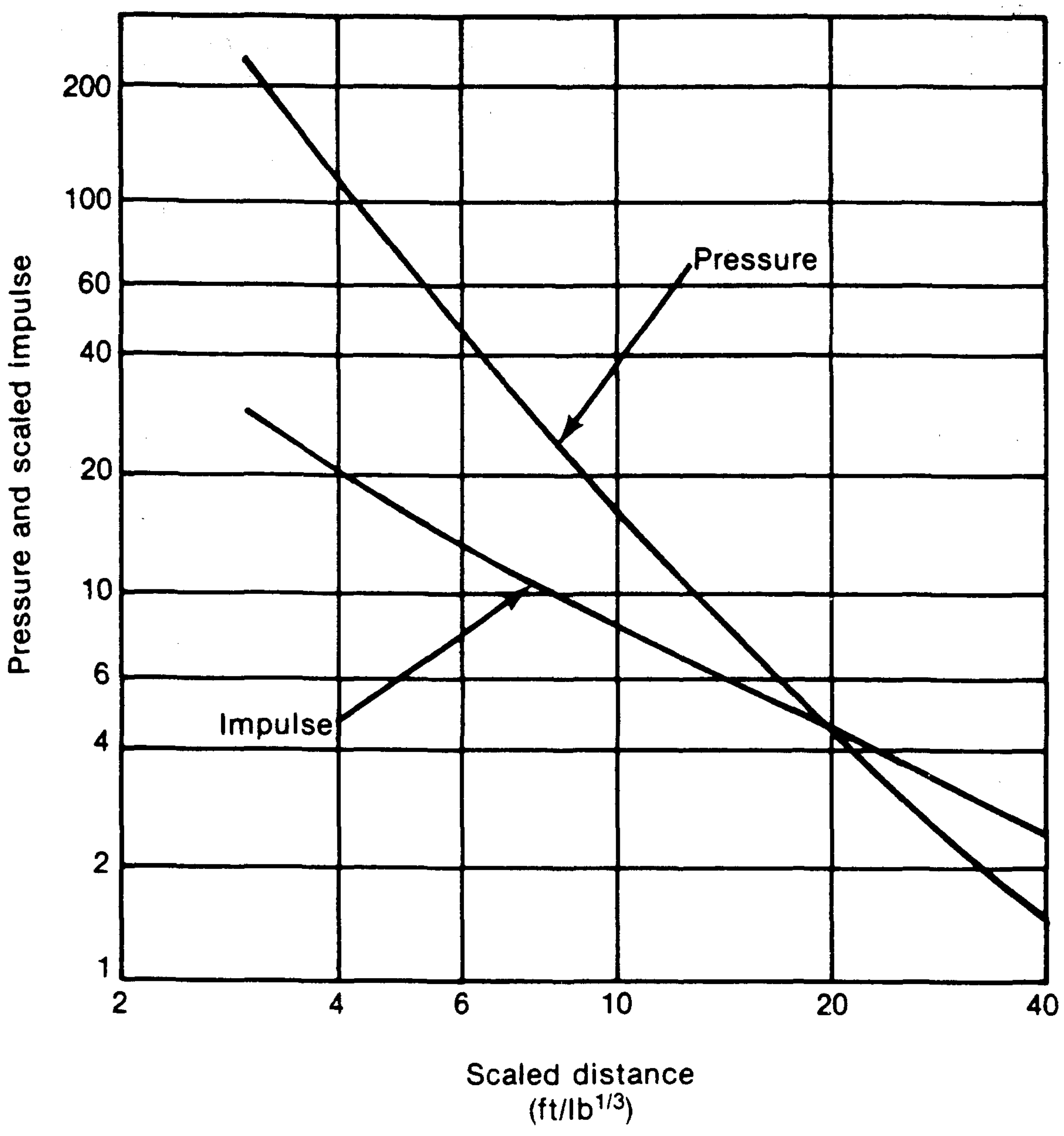


Figure 136. Peak Pressure and Scaled Positive Impulse Versus Scale Distance for XM37 RAP Propellant Aft Grain Simulated Billets. L/D=10.22:1.

Table 90. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse For XM37 RAP Propellant Aft Grain Ro Con Shipping Container, L/D=0.83:1.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	230.68	1590.51	36.99	331.95	22.000	8.727	2.53	17.42	4.45	39.91
4.000	1.587	130.78	901.74	17.55	157.51	23.000	9.124	2.36	16.26	4.31	38.64
5.000	1.983	78.51	541.34	1.70	105.01	24.000	9.521	2.22	15.28	4.16	37.37
6.000	2.380	50.21	346.19	9.20	82.54	25.000	9.917	2.09	14.44	4.02	36.10
7.000	2.777	33.98	234.28	7.90	70.90	26.000	10.314	1.99	13.72	3.88	34.82
8.000	3.174	24.13	166.41	7.14	64.08	27.000	10.711	1.90	13.11	3.74	33.56
9.000	3.570	17.86	123.15	6.65	59.71	28.000	11.108	1.82	12.58	3.60	32.30
10.000	3.967	13.68	94.35	6.32	56.68	29.000	11.504	1.76	12.13	3.46	31.06
11.000	4.364	10.80	74.47	6.07	54.43	30.000	11.901	1.70	11.73	3.33	29.84
12.000	4.760	8.74	60.30	5.87	52.65	31.000	12.298	1.65	11.40	3.19	28.64
13.000	5.157	7.24	49.91	5.70	51.13	32.000	12.694	1.61	11.11	3.06	27.46
14.000	5.554	6.11	42.12	5.55	49.78	33.000	13.091	1.58	10.86	2.93	26.31
15.000	5.960	5.24	36.15	5.41	48.51	34.000	13.488	1.55	10.66	2.81	25.18
16.000	6.347	4.57	31.49	5.27	47.28	35.000	13.884	1.52	10.48	2.68	24.09
17.000	6.744	4.03	27.80	5.13	46.07	36.000	14.281	1.50	10.34	2.57	23.02
18.000	7.141	3.60	24.84	5.00	44.87	37.000	14.678	1.48	10.22	2.45	21.99
19.000	7.537	3.25	22.42	4.86	43.65	38.000	15.075	1.47	10.13	2.34	20.99
20.000	7.934	2.96	20.44	4.73	42.41	39.000	15.471	1.46	10.06	2.23	20.03
21.000	8.331	2.73	18.80	4.59	41.17	40.00	15.868	1.45	10.01	2.13	19.09

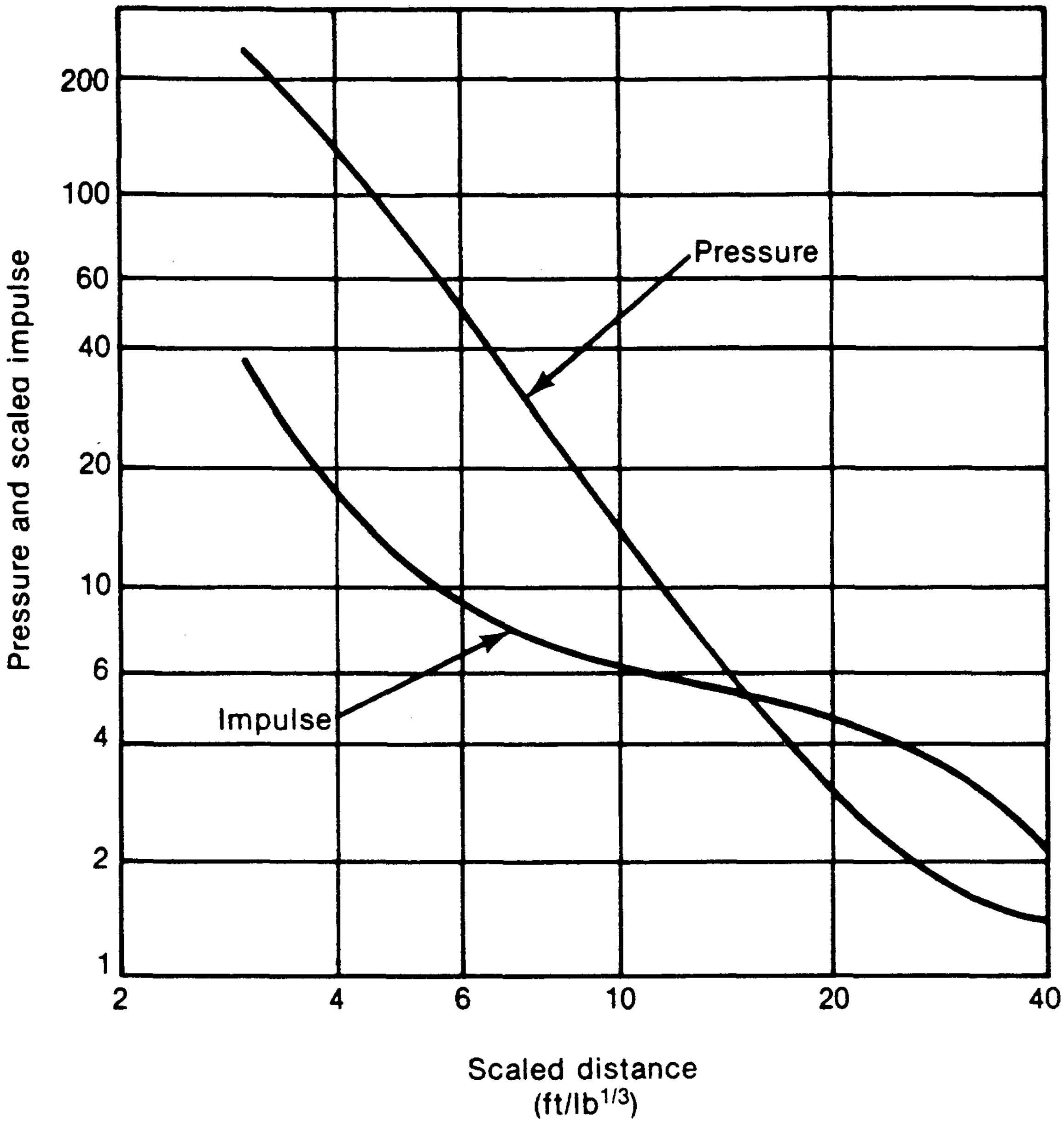


Figure 137. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for XM37 RAP Propellant AFT Grain Ro Con Shipping Container, L/D=0.83:1.

SUMMARY OF PROPELLANTS

A total of 14 bulk propellants and end items were tested in shipping containers (both orthorhombic and cylindrical), in dryer beds. and hoppers simulating manufacturing and transport configurations. The propellants were representative of single-base. double-base and composite types of propellants. The propellants were also representative of both small and large caliber types.

Black Powder. Benite, BS-Naco, M1 and M6 propellants all had pressure and scaled positive impulse values of less than expected for equal amounts of TNT at all of the scaled distances of the experiments when tested in the various geometries. All of the other propellants tested had pressure and impulse values that varied from less than to equal to or greater than expected results for hemispherical TNT surface bursts at the same scaled distances. The measured values were dependent upon the geometry in which it was tested. Newer types of propellants such as JA-2. DIGL-RP and M31A1E1 were more energetic than the other prropellants tested. Generally the pressure and scaled positive impulse values were dependent upon the geometry in which it was tested.

Generally, single and double-base propellants had a tendency to have pressure and impulse values greater than expected at close-in scaled distances equal to or less than 2.14 $m/kg^{1/3}$ (5.4 $ft/lb^{1/3}$) and less than expected at scaled distances equal to or greater than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$). These results were obtained with some explosives when tested in similar configurations and L/D ratios. The effect of geometry were prevalent in the reported values. Multiple peaks occurred when the L/D ratio was greater than 1:1 at the mid to far-field scaled distances equal to or greater than 2.14 $m/kg^{1/3}$ (5.4 $ft/lb^{1/3}$).

Peak pressure and scaled positive impulse values for orthorhombic containers with a L/D ratio equal to or less than 1:1 had lower pressure and impulse values than when the L/D ratio was greater than 1:1.

Propellants tested in geometries and configurations representing manufacturing situations where the propellant was processed with a high content of moisture failed to detonate. This was also found to be the case when thickness of the material was less than 152.4 mm (6 in) for sheet or dry propellants.

Single-base and double-base propellants had higher TNT equivalency values than composite propellants. The percentage of nitrocellulose for the single-base propellants and the nitroglycerine/nitrocellulose contents for the double-base propellants affected the measured values. The higher the NC or NC/NG content the greater the pressure and impulse values.

The foreign propellants (JA-2 and DIGL) propellants had higher pressure and impulse values when compared to the more common large caliber propellants.

The end item configuration tests were generally varied as to the type of test. The pressure values for the XM37 RAP propellant were greater than those obtained for the M1 propellant in the standard propelling charge container. The M1 propellant values were also less than those obtained for the bulk tests and this was attributed to the energy required to rupture the containers.

A summary of peak pressure and scaled positive impulse values versus scaled distances for all of the propellants are given in Table 91. The TNT equivalency versus scaled distance for the geometries tested are given in Table 92.

Table 91. Summary of Peak Pressure and Scaled Positive Impulse for Bulk

Test Materials	Geometry	Physical Characteristics	Configuration	L/D Ratio (x:1)	Peak P Z = 3.0 P	I	
Black Power	Orthorhombic	Dry Powder	Tote Bin/Glaze Barrel	1:1	56.5	12.4	
Benite Propellant	Orthorhombic	Extruded Strands	Shipping Container	1:1	41.7	15.3	
	Orthorhombic	Extruded Strands	Shipping Container	1:1	61.1	14.3	
B3-NACO Propellant	Cylindrical	Multi-Perforated Grain	Shipping Container	1.7:1	54.3	8.64	
	Orthorhombic	Multi-Perforated Grain	Shipping Container	1.75:1	44.05	8.74	
	Truncated Prism	Multi-Perforated Grain	Hopper	0.43:1	57.85	12.26	
DIGL-RP Propellant							
I5420	Orthorhombic	Stick Propellant	Shipping Container	0.5:1	355.87	36.88	
I5421	Cylindrical	Stick Propellant	Shipping Container	1.1:1	160.15	28.47	
I5422	Orthorhombic	Stick Propellant	Shipping Container	0.5:1	258.5	25.14	
JA-2 Propellant	Cylindrical	Multi-Perforated Grain	Shipping Container	1:1	268.28	33.48	
	Orthorhombic	Multi-Perforated Grain	Dryer Bed	0.25:1	210.18	21.14	
M1 Propellant	Orthorhombic	Single Perforation	--	1:1	65.4	10.77	
	Orthorhombic	Multi-Perforated	--	1:1	85.91	16.87	
M6 Propellant	Cylindrical	Multi-Perforated	Shipping Drum	1.7:1	108.71	19.30	
	Truncated Prism	Multi-Perforated	Closed Hopper	0.43:1	52.55	10.73	
	Truncated Prism	Multi-Perforated	Open Hopper	0.3:1	46.99	10.02	
M10 Propellant	Orthorhombic	Single Perforation	Shipping Container	1.8:1	163.5	55.48	
	Orthorhombic	Single Perforation	Shipping Container	0.6:1	136.37	38.36	
M26E1 Propellant	Cylindrical	Multi-Perforated	Blender Barrel	1.1:1	108.77	17.32	
	Orthorhombic	Multi-Perforated	Dryer Bed	0.5:1	149.85	19.29	
	Orthorhombic	Multi-Perforated	Dropped Buggy	1:1	256.32	27.09	1
	Cylindrical	Multi-Perforated	Shipping Drum	1.7:1	237.77	21.02	
M30A1 Propellant	Cylindrical	Single Perforation	Shipping Container	1.7:1	217.95	23.38	
	Cylindrical	Multi-Perforated	Shipping Container	1.7:1	186.12	26.46	
	Orthorhombic	Single Perforation	Dryer Bed	0.15	182.12	24.22	
	Orthorhombic	Multi-Perforated	Dryer Bed	0.15	178.78	18.07	
M31A1E1 Propellant	Orthorhombic	Slotted Stick	Shipping Container	0.26:1	213.93	21.49	
	Orthorhombic	Slotted Stick	Shipping Container	0.26:1	198.93	17.36	
N-5 Propellant	Cylindrical	Loose Powder	Shipping Container	1.7:1	136.18	18.15	
	Cylindrical	Cast Sheet	Carpet Rolls	1:1	180.82	23.77	
	Orthorhombic	Loose Powder	Charge Buckets	0.[illegible]4:1	129.92	18.88	
	Orthorhombic	Thin Sheet	Conveyor Belt	0.03:1	80.14	12.40	
	Cylindrical	Cast Grid	Rocket Grain MK43-1	9.54:1	122.57	12.80	
WC844 Ball Powder	Cylindrical	Ball Powder	Shipping Container	1.6:1	356.96	29.43	1
	Orthorhombic	Ball Powder	Dryer Bed	0. :1	140.90	14.47	
XM37 Propellant RAP 549 Forward and AFT Grain	Cylindrical	Extruded Grain	Single Forward Grain	0.76:1	145.4	30.38	
	Cylindrical	Extruded Grain	FWD Extruded Billet	9.09:1	196.62	31.24	1
	Cylindrical	Extruded Grain	Ro-Con Drum (Fwd)	1.54:1	234.21	33.31	1
	Cylindrical	Extruded Grain	Single Aft Grain	0.64:1	228.44	28.70	1
	Cylindrical	Extruded Grain	Aft Ro-Con Drum	0.83:1	230.68	36.99	1
	Cylindrical	Extruded Grain	Aft Extruded Billet	10.22:1	--	--	

ed Positive Impulse for Bulk Propellants and End Items

Configuration	L/D Ratio (x:1)	Peak Pressure (psi) & Scaled Positive Impulse (psi - msec/w$^{1/3}$) Z = 3.0 P	Z = 3.0 I	Z = 40 P	Z = 40 I	Z = 5.4 P	Z = 5.4 I	Z = 9.0 P	Z = 9.0 I	Z = 18.0 P	Z = 18.0 I	Z = 40.0 P	Z = 40.0 I
Bin/Glaze Barrel	1:1	56.5	12.4	33.1	9.9	18.6	7.7	7.1	4.9	2.09	2.4	0.56	0.98
ing Container	1:1	41.7	15.3	23.9	10.5	14.2	7.6	6.3	4.7	2.1	2.4	0.56	0.73
ing Container	1:1	61.1	14.3	36.3	9.34	21.1	6.1	8.3	3.59	2.4	2.29	0.8	0.73
ing Container	1.7:1	54.3	8.64	28.5	6.79	15.2	5.27	5.8	3.43	1.93	1.92	0.73	1.02
ing Container	1.75:1	44.05	8.74	24.44	6.21	13.11	4.37	4.47	2.44	10.1	1.14	0.18	0.52
r	0.43:1	57.85	12.26	31.26	9.79	17.02	7.56	6.42	4.72	1.94	2.33	0.59	0.94
ing Container	0.5:1	355.87	36.88	192.74	21.97	75.77	15.86	15.12	11.2	4.00	6.32	1.67	2.24
ing Container	1.1:1	160.15	28.47	89.94	14.69	45.57	11.84	15.55	11.11	5.41	5.76	1.34	1.67
ing Container	0.5:1	258.5	25.14	113.22	17.11	42.7	12.94	10.81	9.21	4.76	5.43	1.51	1.72
ing Container	1:1	268.28	33.48	138.85	19.16	57.49	15.68	15.11	13.69	6.12	6.53	1.47	1.92
Bed	0.25:1	210.18	21.14	102.2	14.69	42.46	11.81	11.52	8.85	4.60	4.59	1.56	1.70
	1:1	65.4	10.77	41.78	9.43	26.32	8.31	10.61	6.48	1.82	2.01	0.1	0.01
	1:1	85.91	16.87	41.86	12.11	21.10	8.67	7.53	5.08	2.37	2.67	0.88	1.47
ng Drum	1.7:1	108.71	19.30	52.68	12.51	25.25	8.50	7.87	4.97	2.14	2.75	0.88	1.40
Hopper	0.43:1	52.55	10.73	30.23	8.75	16.15	6.81	5.86	4.22	2.04	2.21	0.77	1.27
Hopper	0.3:1	46.99	10.02	28.06	7.87	15.91	6.16	6.02	4.13	1.81	2.41	0.69	1.27
ng Container	1.8:1	163.5	55.48	88.95	33.88	41.27	17.38	10.92	6.44	2.72	3.66	1.03	1.67
ng Container	0.6:1	136.37	38.36	86.66	37.04	40.83	20.09	11.90	6.00	3.01	3.41	1.34	1.28
r Barrel	1.1:1	108.77	17.32	62.03	13.23	34.53	10.00	12.74	6.20	3.28	3.24	0.69	1.54
Bed	0.5:1	149.85	19.29	68.27	15.72	32.13	11.60	10.41	7.46	3.09	4.10	1.19	2.05
d Buggy	1:1	256.32	27.09	135.57	20.47	69.76	15.28	22.51	9.28	4.85	4.72	0.83	2.17
ng Drum	1.7:1	237.77	21.02	98.93	15.84	52.53	12.72	12.07	7.14	3.08	3.61	1.04	1.65
ng Container	1.7:1	217.95	23.38	92.92	16.07	40.66	11.07	11.57	6.18	[illegible]	3.13	[illegible]	1.75
ng Container	1.7:1	186.12	26.46	78.99	16.18	34.60	10.77	10.06	6.32	2.64	3.29	0.91	1.07
Bed	0.15	182.12	24.22	83.19	17.27	38.07	12.35	10.94	7.27	2.39	3.85	0.53	2.08
Bed	0.15	178.78	18.07	77.90	13.37	34.86	9.93	10.31	6.20	2.70	3.47	0.92	1.90
ng Container	0.26:1	213.93	21.49	90.59	15.44	39.86	10.88	11.47	6.07	2.97	2.73	1.01	1.09
ng Container	0.26:1	198.93	17.36	79.60	13.17	33.57	9.88	9.59	6.06	2.71	3.12	1.19	1.45
ng Container	1.7:1	136.18	18.15	61.46	13.73	28.76	10.26	9.26	6.25	2.73	3.19	1.08	1.47
Rolls	1:1	180.82	23.77	76.74	15.30	33.67	10.68	9.77	6.66	2.54	3.58	0.86	1.09
Buckets	0.'4:1	129.92	18.88	58.27	13.62	27.17	9.87	8.8	5.97	2.70	3.29	1.13	1.89
or Belt	0.03:1	80.14	12.40	39.07	9.99	19.70	7.98	7.16	5.43	2.47	3.23	1.12	1.77
Grain MK43-1	9.54:1	122.57	12.80	69.04	13.72	38.41	12.69	14.57	8.59	4.15	3.92	1.06	1.83
ng Container	1.6:1	356.96	29.43	153.77	19.50	61.43	13.31	15.30	7.79	4.37	4.35	1.49	1.83
Bed	0. :1	140.90	14.47	57.20	11.14	26.69	8.93	12.38	6.69	4.55	4.78	1.80	2.52
Forward Grain	0.76:1	145.4	30.38	92.45	20.10	50.06	13.78	16.55	7.97	3.98	4.25	1.27	2.14
truded Billet	9.09:1	196.62	31.24	116.82	21.00	64.35	14.54	21.79	8.47	5.11	4.50	1.33	2.19
Drum (Fwd)	1.54:1	234.21	33.31	122.19	22.94	60.04	15.84	17.77	8.80	4.02	4.26	1.30	2.02
Aft Grain	0.64:1	228.44	28.70	116.39	20.41	58.24	14.77	20.10	9.02	5.36	4.91	1.46	2.43
-Con Drum	0.83:1	230.68	36.99	130.78	17.55	65.18	10.48	17.86	6.65	3.60	5.00	1.45	2.13
truded Billet	10.22:1	--	--	--	--	--	--	20.09	9.01	5.37	4.91	1.45	2.43

Table 92. Summary of Peak Pressure and Scaled Positive Impulse, TNT Ec

Test Materials	Geometry	Physical Characteristics	Configuration	L/D Ratio (x:1)	P Z = 3.0 P	
Black Power	Orthorhombic	Dry Powder	Tote Bin/Glaze Barrel	1:1	0.3	0.
Benite Propellant	Orthorhombic	Extruded Strands	Shipping Container	1:1	0.2	0.
	Orthorhombic	Extruded Strands	Shipping Container	1:1	0.3	0.
B3-NACO Propellant	Cylindrical	Multi-Perforated Grain	Shipping Container	1.7:1	0.2	0.
	Orthorhombic	Multi-Perforated Grain	Shipping Container	1.75:1	0.2	0.
	Truncated Prism	Multi-Perforated Grain	Hopper	0.43:1	0.3	0.
DIGL-RP Propellant						
I5420	Orthorhombic	Stick Propellant	Shipping Container	0.5:1	3.7	2.
I5421	Cylindrical	Stick Propellant	Shipping Container	1.1:1	1.2	2.
I5422	Orthorhombic	Stick Propellant	Shipping Container	0.5:1	2.3	1.
JA-2 Propellant	Cylindrical	Multi-Perforated Grain	Shipping Container	1:1	2.8	2.
	Orthorhombic	Multi-Perforated Grain	Dryer Bed	0.25:1	1.8	1.
M1 Propellant	Orthorhombic	Single Perforation	—	1:1	0.3	0.
	Orthorhombic	Multi-Perforated	—	1:1	0.6	0.
M6 Propellant	Cylindrical	Multi-Perforated	Shipping Drum	1.7:1	0.8	0.
	Truncated Prism	Multi-Perforated	Closed Hopper	0.43:1	0.3	0.
	Truncated Prism	Multi-Perforated	Open Hopper	0.3:1	0.3	0.
M10 Propellant	Orthorhombic	Single Perforation	Shipping Container	1.8:1	1.4	5.
	Orthorhombic	Single Perforation	Shipping Container	0.6:1	1.0	3.
M26E1 Propellant	Cylindrical	Multi-Perforated	Blender Barrel	1.1:1	0.8	0.
	Orthorhombic	Multi-Perforated	Dryer Bed	0.5:1	1.2	1.
	Orthorhombic	Multi-Perforated	Dropped Buggy	1:1	2.5	1.
	Cylindrical	Multi-Perforated	Shipping Drum	1.7:1	2.2	1.
M30A1 Propellant	Cylindrical	Single Perforation	Shipping Container	1.7:1	2.0	1.
	Cylindrical	Multi-Perforated	Shipping Container	1.7:1	1.5	1.
	Orthorhombic	Single Perforation	Dryer Bed	0.15	1.6	1.
	Orthorhombic	Multi-Perforated	Dryer Bed	0.15	1.5	0.
M31A1E1 Propellant	Orthorhombic	Slotted Stick	Shipping Container	0.26:1	2.1	1.
	Orthorhombic	Slotted Stick	Shipping Container	0.26:1	1.6	1.
N-5 Propellant	Cylindrical	Loose Powder	Shipping Container	1.7:1	1.0	0.
	Cylindrical	Cast Sheet	Carpet Rolls	1:1	1.4	1.
	Orthorhombic	Loose Powder	Charge Buckets	0.14:1	1.0	1.
	Orthorhombic	Thin Sheet	Conveyor Belt	0.03:1	0.6	0.
	Cylindrical	Cast Grid	Rocket Grain MK43-1	9.54:1	0.9	0.
WC844 Ball Powder	Cylindrical	Ball Powder	Shipping Container	1.6:1	3.8	2.
	Orthorhombic	Ball Powder	Dryer Bed	0.1:1	1.1	0.
XM37 Propellant RAP 549 Forward and AFT Grain	Cylindrical	Extruded Grain	Single Forward Grain	0.76:1	1.3	2.
	Cylindrical	Extruded Grain	FWD Extruded Billet	9.09:1	1.7	2.
	Cylindrical	Extruded Grain	Ro-Con Drum (Fwd)	1.54:1	1.8	2.
	Cylindrical	Extruded Grain	Single Aft Grain	0.64:1	2.0	1.
	Cylindrical	Extruded Grain	Aft Ro-Con Drum	0.83:1	1.7	2.
	Cylindrical	Extruded Grain	Aft Extruded Billet	10.22:1	--	--

tive Impulse, TNT Equivalency Values for Bulk Propellants and End-Items.

	L/D Ratio	Peak Pressure (psi) & Scaled Positive Impulse (psi - msec/$w^{1/3}$)											
		Z = 3.0		Z = 40		Z = 5.4		Z = 9.0		Z = 18.0		Z = 40.0	
ion	(x:1)	P	I	P	I	P	I	P	I	P	I	P	I
Barrel	1:1	0.3	0.5	0.4	0.5	0.4	0.5	0.4	0.5	0.3	0.4	0.2	0.4
iner	1:1	0.2	0.9	0.1	0.7	0.3	0.4	0.2	0.4	0.2	0.4	0.1	0.2
iner	1:1	0.3	0.7	0.4	0.6	0.5	0.3	0.5	0.3	0.1	0.4	0.3	0.2
iner	1.7:1	0.2	0.3	0.2	0.3	0.2	0.1	0.3	0.3	0.2	0.3	0.2	0.3
iner	1.75:1	0.2	0.4	0.2	0.3	0.2	0.2	0.3	0.2	0.1	0.2	0.1	0.1
	0.43:1	0.3	0.5	0.3	0.5	0.3	0.5	0.3	0.4	0.3	0.4	0.2	0.4
iner	0.5:1	3.7	2.9	4.1	1.9	2.1	1.5	1.3	1.8	1.2	1.9	2.1	1.2
iner	1.1:1	1.2	2.1	1.5	0.9	1.2	0.95	1.4	1.8	2.1	1.7	1.2	0.8
iner	0.5:1	2.3	1.5	1.9	1.2	1.1	1.0	0.8	1.3	1.6	1.5	1.6	0.8
iner	1:1	2.8	2.5	2.3	1.4	2.0	1.8	1.4	1.9	2.7	2.1	1.6	1.0
	0.25:1	1.8	1.1	1.7	0.9	1.1	0.9	0.9	1.2	1.6	1.1	1.7	0.8
	1:1	0.3	0.4	0.3	0.4	0.5	0.5	0.6	0.7	0.7	0.7	0.1	0.1
	1:1	0.6	0.3	0.5	0.7	0.5	0.6	0.5	0.5	0.4	0.5	0.6	0.7
	1.7:1	0.8	0.9	0.7	0.7	0.7	0.6	0.4	0.5	0.4	0.5	0.7	0.6
	0.43:1	0.3	0.4	0.3	0.4	0.3	0.4	0.2	0.4	0.3	0.4	0.4	0.5
	0.3:1	0.3	0.4	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.4	0.3	0.5
iner	1.8:1	1.4	5.3	1.4	3.8	1.4	1.9	0.9	0.7	0.6	0.8	0.7	0.8
iner	0.6:1	1.0	3.1	1.2	5.2	1.2	2.0	1.1	0.9	0.7	0.7	1.3	0.5
	1.1:1	0.8	0.9	0.8	0.8	1.0	0.8	1.1	0.7	0.9	0.7	0.3	0.7
	0.5:1	1.2	1.0	1.0	1.0	0.9	1.0	0.8	0.9	0.8	1.0	1.0	1.1
	1:1	2.5	1.3	2.5	1.7	2.5	1.6	2.8	1.3	1.8	1.2	0.4	1.2
	1.7:1	2.2	1.3	1.6	1.1	1.3	1.0	1.0	0.9	0.8	0.8	0.7	0.8
iner	1.7:1	2.0	1.4	1.5	1.1	1.2	0.9	1.0	0.7	0.7	0.7	0.5	0.9
iner	1.7:1	1.5	1.7	1.5	1.1	1.1	0.9	0.8	0.7	0.6	0.7	0.6	0.4
	0.15	1.6	1.5	1.3	1.2	1.1	1.1	0.9	0.9	0.4	0.9	0.2	1.1
	0.15	1.5	0.9	1.3	0.8	1.0	0.7	0.7	0.7	0.7	0.8	0.6	1.0
iner	0.26:1	2.1	1.3	1.6	0.9	1.6	1.2	1.0	0.7	0.8	0.4	0.6	0.4
iner	0.26:1	1.6	1.5	1.4	0.7	1.3	0.6	0.5	0.6	0.9	0.5	0.8	0.7
iner	1.7:1	1.0	0.9	0.9	0.9	0.8	0.8	0.7	0.7	0.6	0.7	0.8	0.7
	1:1	1.4	1.3	1.3	1.1	1.2	0.9	0.6	0.8	0.5	0.8	0.4	0.6
	0.14:1	1.0	1.0	0.9	0.9	0.7	0.7	0.6	0.7	0.6	0.7	0.9	0.9
	0.03:1	0.6	0.5	0.5	0.4	0.5	0.5	0.5	0.6	0.5	0.7	0.9	0.9
K43-1	9.54:1	0.9	0.8	1.0	0.9	1.2	1.1	1.4	1.2	1.3	0.9	0.8	0.9
iner	1.6:1	3.8	2.3	3.1	1.3	2.0	1.2	1.5	1.0	1.5	1.1	1.7	0.9
	0.1:1	1.1	0.7	0.7	0.4	0.5	0.7	1.0	0.7	1.6	1.2	2.6	1.5
Grain	0.76:1	1.3	2.1	1.7	1.7	2.3	1.3	1.4	1.0	1.3	1.0	1.1	1.2
illet	9.09:1	1.7	2.1	2.3	1.8	2.7	1.5	2.4	1.2	2.0	1.1	1.2	1.2
wd)	1.54:1	1.8	2.2	2.5	2.5	2.8	2.5	1.8	1.2	1.4	1.0	1.2	1.1
in	0.64:1	2.0	1.9	2.5	1.5	2.3	1.6	2.1	1.3	2.2	1.3	1.6	1.4
n	0.83:1	1.7	2.4	2.7	2.6	3.4	2.9	1.8	1.6	1.1	1.3	1.6	1.2
illet	10.22:1	--	--	--	--	--	--	2.0	1.2	2.1	1.3	1.5	1.4

INTRODUCTION

Pyrotechnics are broadly defined as explosives. However, pyrotechnic mixtures behave differently than either explosives or propellants. Pyrotechnics are unique and can be defined as solid mixtures which are self-contained (own fuel and oxidizer), self-sustained and when intimately mixed, create the effects of timing, heat, gas, sound, aerosol dispersion, electromagnetic radiation, or a combinatin of these which produce the maximum output from the least volume. Generally, pyrotechnics are type classified within their broadly defined categories by their intended use.

Pyrotechnic mixtures can be the least energetic in terms of producing an explosion as compared to either propellants or explosives. Pyrotechnic mixtures are generally considered to be the most sensitive to friction, electrical spark, impact, and heat-type stimuli. Because of the ease of initiation these materials can release their energy much easier than either high explosives or propellants. Normally, the energy when released is under control. However, there are occassions when pyrotechnics can cause an explosive reaction. Explosions are possible when the pyrotechnic mixtures are confined and in dry powder form. There have also been incidents during mixing when the mixtures are wet, where explosions causing considerable damage have occurred. Accidents have been reported when an explosion has occurred during mixing, granulation, reaming pressing sieving/screening, weighing and filling. During an incident/accident investigation and analysis [40] [44] it was noted that aproximately 23% of all pyrotechnic accidents/incidents resulted in some form of an explosion. This is significant because pyrotechnic mixtures are not normally considered to be explosive in nature.

Determining the TNT equivalency of a pyrotechnic mixture requires that an explosive booster ranging from 1 to 10% be used. Critics of this procedure say that the addition of a booster is not relevant to a given manufacturing operation. However, due to the high precentage of explosive occurrences it becomes imperative that the output energy be determined. The boostering effect is factored out and the reported values are the actual contribution of the particluar pyrotechnic mixture. The particular pyrotechnic mixtures considered for investigation under this study were involved in costly incident/accident scenarios.

TNT equivalency tests were conducted on primer mixtures, illuminants and heat producing delay type mixtues. Primer mixtures are used in the ignition circuit of explosive fuze trains and these mixtures which contain primary explosives such as lead azide, tetryl, or lead styphante are very energetic with TNT equivalencies as high as 70% when compared to hemispherical TNT surface bursts. Specifically, the aluminum/potassium perchlorate and titanium subhydride/potassium perchlorate systems are considered as primary ignition mixtures for blasting caps and detonators. These mixtures have TNT equivalency values of approximately 50%. Illuminants are gaseous mixtures that primarily produce light. These types of pyrotechnics usually consist of a fine metal powder and a strong oxidizer. TNT equivalency values of 50 to 65% have been measured for specific illuminant mixtures. Other illuminant mixtures also include IR decoy flare mixture, photoflash mixtures, signals and tracer mixtures. IR decoy flare mixtures and photoflash powders have TNT equivalency values of approximately 50%. Tracer mixtures and tracer ignition mixtures have low TNT equivalency values ranging from 5 to 15%. Smoke mixtures have TNT equivalency values ranging from 5 to 15%. Heat- producing-type pyrotechnics such as starter mixtures and ignition mixtures can be gaseous. TNT equivalency values for these type mixtures vary significantly, based primarily upon the amount of gas produced. Gasless delay mixtures do not generally produce sufficient gas to measure a TNT equivalency value.

The specific mixtures investigated as under this study included R284 Tracer mixture, I559 Ignition mixture, I560 Subigniter mixture, aluminum/potassium perchlorate ignition Mixture, boron/calcium chromate delay mixture, M49A1 Trip Flare mixture, M49A1 First Fire Ignition mixture and M314A3 Illuminant Flare mixture. In addition to these mixtures cited Mk24 White Flare mixture, M301A2/A3 White Flare mixture. M206 IR Decoy Flare mixture, Photo Flash Powders 555, 600 and 1025. titanium subhydride/potassium perchlorate, red, green, violet, and yellow smoke mixtures, CS Riot Control Mixture, CS Pyrotechnic Mixture, CS Chemical Agent, M80 Detonator Simulator mixture, first fire mixture, fuel mixture, special igniter mixture, Starter Mixture III, Starter Mixture VI, and Starter Mixture Drawing B143-7-1 were tested for TNT equivalency values under several seperate studies [45][46] are included in Table 93.

Table 93. TNT Equivalency of Selected Pyrotechnics[46]

	Sample Material	TNT Equivalency %
1.	Mk24 White Flare Mixture	50
2.	M301A2/A3 White Flare Mixture	30
3.	IR Decoy Flare Mixture	45
4.	PFP555 Photo Flash Mixture	36
5.	PFP600 Photo Flash Mixture	54
6.	PFP1025 Photo Flash Mixture	36
7.	Green Smoke IV, B143-2-1	4
8.	Green Smoke, B143-2-6	11
9.	Green Smoke, No. 8797998	8
10.	Green Smoke, B143-2-5	3
11.	Red Smoke III, B143-3-1	7
12.	Red Smoke, B143-3-7	6
13.	Red Smoke, C143-3-6	8
14.	Red Smoke, B142-3-5	6
15.	Red Smoke VII, B143-3-4	6
16.	Yellow Smoke VI, B143-4-1	5
17.	Yellow Smoke, B143-4-7	7
18.	Yellow Smoke, B143-4-6	7
19.	Yellow Smoke, B143-4-8	6
20.	Violet Smoke IV, B143-5-1	6
21.	Violet Smoke, B143-5-2	9
22.	CS Pyrotechnic Mixture, B143-14-10	34

Sample Material	TNT Equivalency %
23. CS Riot Mixture, B143-14-7	22
24. CS Chemical Agent	12
25. M80 Detonator Simulator	80
26. First Fire Mixture, No. PA92551742	30
27. Fuel Mixture VI, B143-10-1	14
28. Special Igniter Mixture, PA SI-193	32
29. Starter Mixture III, B143-7-6	16
30. Starter Mixture VI, B143-7-3	20
31. Starter Mixture, B143-7-1	6

TNT EQUIVLENCY OF R284 TRACER MIXTURE, I559 IGNITER MIXTURE AND I560 SUBINGITER MIXTURE[39]

OBJECTIVE

The objective of this work was to determine the explosive output from detonating quantities of R284 Tracer Mixture, I560 Subingniter, and I559 Igniter Mixture in configurations representative of the actual plant production environment. The measure peak pressure and positive impulse values were compared to the known characteristics of hemispherical TNT to determine TNT equivalency.

MATERIALS

R284 tracer mixture, Drawing Number B1052246, is the main charge tracer mixture used in the 5.58 mm, 0.30 caliber, 7.62mm NATO bullet and the 0.50 caliber ball ammunitions. R284 tracer mixture consists of strontium nitrate/polyvinyl chloride/(50/100 mesh) magnesium in 53.7/18.1/28.2% by weight, respectively. I559 igniter mixture consists of I136 premix (90% strontium nitrate and 10% calcium resinate)/and a premix (23.3% lead dioxide and 77.7% magnesium) in 79.5/20.5% by weight. I560 subigniter mixture consists of magnesium/strontium nitrate/-strontium peroxide/polyvinyl chloride 27.5/27.5/30/15% by weight, respectively.

TEST SETUP

Each material was tested in three basic configurations consisting of a machine hopper, rest magazine, and storage containers for the automatic feed option. The mixtures were tested in 0.91, 1.36,3.63, 4.08, 4.54, 6.35, 6.8, 29.5, 34, and 49.9 kg (2, 3, 8, 9, 10, 15 65, 75, and 110 lb) quantities. All tests were conducted in two basic cylinder configurations.

INSTRUMENTATION

Twelve piezoelectric pressure transducers were mounted flush with the ground surface in a 90-degree array on sand-filled runways. The scaled distance ranged from 1.19 to 15.87 $m/lg^{1/3}$ (3.0 to 40.0 $ft/lb^{1/3}$).

RESULTS

Results of the R284 Tracer Mixture are given in Table 94. The I559 mixture results are given in Table 95. The results of the I560 Subigniter Mixture are given in Table 96.

DISCUSSION

Peak pressure values for the R284 Tracer Mixture in the rubber cylinder were significantly less than expected at all scaled distances of the experiment. The pressure values were 173, 149, 75.1, 33.7, 9.17, and 4.07 kPa (25.2, 21.6, 10.9, 4.89, 1.33, and 0,59 psi) at scaled distances of 1.19, 1.61, 2.13, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.05, 5.38, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 0.05, 0.15, 0.14, 0.17, 0.06, and 0.14 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were on the same order of magnitude as the pressure values. The scaled positive impulse values were 54.2, 60.8, 50.7, 29.2, 13.9, and 5.56 kPa-ms/kg$^{1/3}$ (6.04, 6.78, 5.65, 3.25, 1.55, and 0.62 psi-ms.lb$^{1/3}$) at scaled distances of 1.19, 1.61, 2.13, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.05, 5.38, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.12, 0.25, 0.27, 0.22, 0.19, and 0.15 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the R284 Tracer Mixture in the aluminum cylinder were similar to the pressure values obtained in the rubber cylinder tests. The pressure values were 137, 108, 50.9, 26.1, 8.62, and 3.17 kPa (19.9, 15.7, 7.38, 3.78, 1.25, and 0.46 psi) at scaled distances of 1.19, 1.61, 2.13, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.05, 5.38, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 0.04, 0.08, 0.06, 0.09, 0.05, and 0.06 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were less than those obtained in the rubber cylinder tests. The scaled positive impulse values were 45.5, 40.6, 37.6, 28.1, 11.3, and 3.59 kPa-ms/kg$^{1/3}$ (5.07, 4.52, 4.19, 3.13, 1.26, and 0.40 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.61, 2.13, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.05, 5.38, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.09, 0.11, 0.15, 0.20, 0.13, and 0.07 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the I559 Igniter Mixture in a rubber cylinder were less than those values obtained for the R284 Tracer Mixture. The pressure values were 138.59, 114.45, 52.52, 23.93, 7.65, and 3.45 kPa (20.1, 16.6, 7.66, 3.47, 1.11, and 0.50 psi) at scaled distances of 1.19, 1.61, 2.13, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.05, 5.38, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 0.03, 0.09, 0.06, 0.08, 0.03, and 0.08 times equal amounts of TNT at the same scaled distances respectively. The scaled positive impulse values were 49.27, 51.42, 53.57, 28.0, 11.67, and 5.47 kPa-ms/kg$^{1/3}$ (5.49, 5.73, 5.97, 3.12, 1.30, and 0.61 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.61, 2.13, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.05, 5.38, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$) respectively. These scaled positive impulse values equate to 0.1, 0.18, 0.3, 0.32, 0.14, and 0.14 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the I559 Igniter Mixture in the aluminun cylinder were similar to the rubber cylinder values. The pressure values were 118.59, 79.98, 35.37, 16.55, 5.38, and 3.03 kPa (17.2, 11.6, 5.13, 2.4, 0.78 and 0.44 psi) at scaled distances of 1.19, 1.61, 2.13, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.05, 5/38, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 0.04, 0.07, 0.03, 0.05, 0.02, and 0.08 times equal amounts of TNT at the same scaled distances respectively. The Scaled positive impulse values were 59.14, 44.24, 35.0, 22.26, 8.97, and 3.59 kPa-ms/kg$^{1/3}$ (6.59, 4.93, 3.90, 2.48, 1.00, and 0.40 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.61, 2.13, 3.57, 71.4, and 15.87 m/kg$^{1/3}$ (3.0, 4.05, 5.38, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.16, 0.16, 0.15, 0.15, 0.1, and 0.08 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the I560 Subigniter Mixture in the rubber cylinder were similar to the results obtained for the I559 Ingiter Mixture. The pressure values were 166.17, 137.21, 66.19, 32.34, 11.93, and 3.59 kPa (24.1, 19.0, 9.6, 4.69, 1.73, and 0.52 psi) at scaled distances of 1.19, 1.61, 2.13, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.05, 5.38, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 0.04, 0.13, 0.11, 0.16, 0.15, and 0.09 times equal amounts of TNT at the same scaled diatances, respectively. The scaled positive impulse values were 68.75, 63.18, 61.74, 36.61, 18.04, and 6.55 kPa-ms/kg$^{1/3}$ (7.66, 7.04, 6.88, 4.08, 2.01, and 0.73 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.61, 2.13, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.05, 5.38, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$) respectively. These scaled positive impulse values equate to 0.2, 0.26, 0.38, 0.33, 0.3, and 0.2 times equal amounts of TNT at the same scaled distances, respectively.

The pressure values for the I560 Subigniter Mixture in the aluminum cylinder were 133.35, 98.18, 55.58, 27.27, 9.73, and 4.62 kPa (19.34, 14.24, 8.06, 4.02, 1.41, and 0.67 psi) at scaled distances of 1.19, 1.61, 2.13, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.05, 5.38, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 0.04, 0.07, 0.07, 0.09, 0.07, and 0.16 times equal amounts of TNT at the same scaled distances respectively. The scaled positive impulse values were 38.5, 56.0, 48.91, 32.93, 15.26, and 5.47 kPa-ms/kg$^{1/3}$ (4.29, 6.24, 5.45, 3.67, 1.7, and 0.61 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.61, 2.13, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.05, 5.38, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.06, 0.19, 0.22, 0.24, 0.2, and 0.13 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) The TNT equivalencies for R284, I559 and I560 tracer components in full-scale production line configurations are 25% or less over the range of scaled distances from 1.19 to 15.87 m/kg$^{1/3}$ (3.0 to 40.0 ft/lb$^{1/3}$). For all materials tested, the impulse equivalencies where somewhat higher than the pressure TNT equivalencies.

(2) Within limits of the experiments, the blast pramaters scale as a cube root function of the charge weight.

(3) The size of booster charge has a significant effect on the measured blast output of R284 Tracer Mixture; however, these observations appear to derive from other factors than mass detonation of the tracer material.

Table 94. Summary of Results for R284 Tracer Mixture.

Configuration	Distance m	Scaled Distance $m/kg^{1/3}$	Scaled Distance $(ft/lb^{1/3})$	Pressure Peak kPa	Pressure Peak (psi)	Scaled Impulse kPa $ms/kg^{1/3}$	Scaled Impulse (psi $ms/kg^{1/3}$)	Pressure Equivalency %	Impulse Equivalency %
Rubber Cylinder	1.24	1.19	(3.00)	173	(25.1)	54.2	(6.04)	5	12
1.13 kg (2.5 lb)	1.68	1.61	(4.05)	149	(21.6)	60.6	(6.78)	15	25
5% Booster	2.23	2.13	(5.38)	75.1	(10.9)	50.7	(5.65)	14	27
	3.72	3.57	(9.00)	33.7	(4.89)	29.2	(3.25)	17	22
	7.44	7.14	(18.00)	9.17	(1.33)	13.9	(1.55)	6	19
	16.6	15.9	(40.00)	4.07	(0.59)	5.56	(0.62)	14	15
Aluminum Cylinder	1.90	1.08	(2.72)	137	(19.9)	45.5	(5.07)	4	9
5.44 kg (12 lb)	2.56	1.46	(3.67)	108	(15.7)	40.6	(4.52)	8	11
2% Booster	3.42	1.94	(4.90)	50.9	(7.38)	37.6	(4.19)	6	15
	5.71	3.25	(8.18)	26.1	(3.78)	26.1	(3.13)	9	20
	11.4	6.47	(16.3)	8.62	(1.25)	11.3	(1.26)	5	13
	25.4	14.4	(36.4)	3.17	(0.46)	3.59	(0.40)	6	7

Table 95. Summary of Results for I559 Igniter Mixture.

Configuration	Distance m	Scaled Distance $m/kg^{1/3}$	Scaled Distance $(ft/lb^{1/3})$	Pressure Peak kPa	Pressure Peak (psi)	Scaled Impulse kPa $ms/kg^{1/3}$	Scaled Impulse (psi $ms/kg^{1/3}$)	Pressure Equivalency %	Impulse Equivalency %
Rubber Cylinder	1.24	1.19	(3.00)	138.59	(20.1)	49.27	(5.49)	3	10
1.13 kg (2.5 lb)	1.68	1.61	(4.05)	114.45	(16.6)	51.42	(5.73)	9	18
5% Booster	2.23	2.13	(5.38)	52.82	(7.66)	53.57	(5.97)	6	30
	3.72	3.57	(9.00)	23.93	(3.47)	28.0	(3.12)	8	21
	7.44	7.14	(18.00)	7.65	(1.11)	11.67	(1.30)	3	14
	16.6	15.90	(40.0)	3.45	(0.50)	5.47	(0.61	8	14
Aluminum Cylinder	1.90	1.19	(3.00)	118.59	(17.2)	59.14	(6.59)	4	16
5.44 kg (12 lb)	2.56	1.61	(4.07)	79.98	(11.6)	44.24	(4.93)	7	16
2% Booster	3.42	2.13	(5.39)	35.37	(5.13)	35.0	(3.90)	3	15
	5.71	3.57	(9.00)	16.55	(2.40)	22.26	(2.48)	5	15
	11.4	7.14	(18.00)	5.38	(0.78)	8.97	(1.00)	2	10
	25.4	15.9	(40.0)	3.03	(0.44)	3.59	(0.40)	8	8

Table 96. Summary of Results for I560 Subigniter Mixture.

Configuration	Distance m	Scaled Distance m/kg$^{1/3}$	Scaled Distance (ft/lb$^{1/3}$)	Pressure Peak kPa	Pressure Peak (psi)	Scaled Impulse kPa ms/kg$^{1/3}$	Scaled Impulse (psi ms/kg$^{1/3}$)	Pressure Equivalency %	Impulse Equivalency %
Rubber Cylinder	1.24	1.19	(3.00)	166.17	(24.10)	66.75	(7.66)	4	20
1.13 kg (2.5 lb)	1.68	1.61	(4.05)	137.21	(19.90)	63.18	(7.04)	13	26
5% Booster	2.23	2.13	(5.38)	66.17	(9.60)	61.74	(6.88)	11	38
	3.72	3.57	(9.00)	32.34	(4.69)	36.61	(4.08)	16	33
	7.44	7.13	(17.98)	11.93	(1.73)	18.04	(2.01)	15	30
	16.6	15.88	(40.02)	3.59	(0.52)	6.55	(0.73)	9	20
Aluminum Cylinder	1.90	1.03	(2.59)	133.35	(19.34)	38.50	(4.29)	4	6
5.44 kg (12 lb)	2.56	1.38	(3.49)	98.18	(14.24)	56.00	(6.24)	7	19
2% Booster	3.42	1.84	(4.65)	55.58	(8.06)	48.91	(5.45)	7	22
	5.71	3.08	(7.77)	27.72	(4.02)	32.93	(3.67)	9	24
	11.4	6.16	(15.53)	9.73	(1.41)	15.26	(1.70)	7	20
	25.4	13.71	(34.55)	4.62	(0.67)	5.47	(0.61)	16	13

TNT EQUIVALENCY OF ALUMINUM/POTASSIUM PERCHLORATE AND BORON/CALCIUM CHROMATE (41)

OBJECTIVE

The objective of these tests was to determine the maximum peak pressure and positive impulse resulting from the detonation of two pyrotechnic mixtures, aluminum and potassium perchlorate (34/66% by weight) and boron/calcium chromate (20/80% by weight). Comparison of results with known characteristics of hemispherical TNT was made to determine TNT equivalency.

MATERIALS

The test materials were boron and calcium chromate (20/80% by weight) supplied by Unidynamics Phonenix, Inc. in a premixed 150 gram quantity, Lot No. 5401 and an aluminum and potassoum perchlorate in 0.45 kg (1 lb) and 0.9 kg (2 lb) quantities, respectively. CSC Hazards Operations Range personnel prepared the 34/66% mixture of aluminum/potassium perchlorate in 0.45 kg (1 lb) quantities in a 5.56 liter jet "Airmix" blender.

TEST SETUP

Airblast output was evaluated for three masses in a cylindrical coniguration for both pyrotechnic mixtures. Physical characteristics of the test items are as follows:

(1) 50 gram quantity of each pyrotechnic mixture was placed in a paper container 3.81 cm^3 (1.5 in^3).

(2) 150 gram quantity of each pyrotechnic mixture was placed in a fiberborad container 6.35 cm^3 (2.5 in^3).

(3) 360 gram quantity of the aluminum/potassium perchlorate mixture was tested in in a fiberboard container with a diameter of 5.08 cm (2 inch) by 14.61 cm (5.75 inch) deep.

INSTRUMENTATION

Twelve pressure transducers were mounted flush with the ground surface in a 90-degree array. Scaled distances ranging from 1.19 to 15.87 m/kg^{1} 3 (3.0 to 40.0 $ft/lb^{1/3}$) were held constant through out the experiment.

RESULTS

The boron/calcium chromate mixture failed to detonate. Therefore, there are no pressure values obtained for this mixture. The results of the 150-g $Al/KClO_4$ tests are given in Table 97 and Figure 138. The results of the 360-g $Al/KClO_4$ tests are given in Table 98 and Figure 139. The combined results are given in Table 99 and Figure 140.

DISCUSSION

Peak pressure values for the 150 gram Aluminum/Potassium perchlorate tests were less than expected at scaled distances equal to or less than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$), greater than expected at scaled dista nces equal to or greater than 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$). The pressure values were 540, 405, 240, 88, 25, and 8.3 kPa (78.36, 58.84 34.86, 12.74, 3.67, and 1.20 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14 and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 0.50, 0.80, 0.96, 1.08, 1.12, and 1.04 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were greater than expected at scaled distances equal to or less than 1.59 $m/kg^{1/3}$ (4.0 $ft/lb^{1/3}$) and less than expected at all scaled distances of the experiment. The scaled positive impulse values were 139, 117, 95, 65, 33, and 14 kPa-$ms/kg^{1/3}$ (15.51, 13.04, 10.64, 7.28, 3.74, and 1.53 psi-$ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14 and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0 and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 0.62, 1.0, 0.61, 0.65, 1.04, and 0.46 times equal amounts of TNT at the same scaled distances, respectively.

The results of the 360 gram $Al/KClO_4$ tests were less than expected at scaled distances equal to or less than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$) and greater than expected at scaled distances equal to or greater than 7.14 $m/kg^{1/3}$ (18.0 $ft/lb^{1/3}$). The pressure values were 610, 345, 196, 80, 27, and 9.1 kPa (88.54, 50.08, 28.40, 11.54, 3.87, and 1.32 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0 and 40.0 $ft/lb^{1/3}$), respectively. These pressure values equate to 0.58, 0.89, 0.86, 0.93, 1.14, and 2.22 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were less than expected at a scaled distance of 1.19 $m/kg^{1/3}$ (3.0 $ft/lb^{1/3}$) greater than expected at a scaled distance of 1.59 $m/kg^{1/3}$ (4.0 $ft/lb^{1/3}$), less than expected at scaled distances of 2.14 and 2.57 $m/kg^{1/3}$ (5.4 and 9.0 $ft/lb^{1/3}$), greater than expected at a scaled distance of 7.14 $m/lg^{1/3}$ (18.0 $ft/lb^{1/3}$) and less than expected at a scaled distance of 15.87 $m/kg^{1/3}$ (40.0 $ft/lb^{1/3}$). The scaled positive impulse values were 110, 108, 102, 80, 44, and 15 kPa-$ms/kg^{1/3}$ (12.12, 12.14, 11.39, 8.92, 4.87 and 1.65, psi-$ms/lb^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14 and 15.87 $m/kg^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 $ft/lb^{1/3}$), respectively. These scaled positive impulse values equate to 0.19, 1.01, 0.65, 0.86, 1.58, and 0.95 times equal amounts of TNT at the same scaled distance, respectively.

The higher pressure and scaled positive impulse values at scaled distances equal to or greater than 3.57 $m/kg^{1/3}$ (9.0 $ft/lb^{1/3}$) are due in part to the fact that the reaction was not a true detonation. The material burns or deflagrates longer in transition to a detonation and this can account for the lower close-in values. The sustained burning does not decay exponentially causing higher values at the far field scaled diatances. The results of all of tests were combined. The combined values are more representative of the reactions which occurred.

Pressure values for the combined results were less than expected at scaled distances equal to or less than 3.57 m/kg$^{1/3}$ (9.0 ft/lb$^{1/3}$), greater than expected at scaled distances equal to or greater than 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$) and less than expected at a scaled distance of 15.87 m/kg$^{1\cdot3}$ (40.0 ft/lb$^{1/3}$). The pressure values were 607, 364, 212, 84, 25, and 7.5 kPa (88.01, 52.72, 30.68, 12.21, 3.68, and 1.09 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 0.58, 0.67, 0.86, 0.95, 1.20, and 0.90 times equal amounts of TNT at the same scaled distances, respectively. The scaled positive impulse values were less than expected at a scaled distance of 1.19 m/kg$^{1/3}$ (3.0 ft/lb$^{1/3}$), greater than expected at a scaled distance of 1.59 m/kg$^{1/3}$ (4.0 ft/lb$^{1/3}$), less than expected at scaled distnces of 2.14 and 3.57 m/kg$^{1/3}$ (5.4 and 9.0 ft/lb$^{1/3}$), greater than expected at a scaled distance of 7.14 m/kg$^{1/3}$ (18.0 ft/lb$^{1/3}$) and less than expected at a scaled distance of 15.87 m/kg$^{1/3}$ (40.0 ft/lb$^{1/3}$). The scaled positive impulse values were 153, 122, 96, 62, 33, and 15.4 kPa-ms/kg$^{1/3}$ (17.09, 13.61, 10.65, 6.90, 3.69, and 1.71 psi-ms/lb$^{1/3}$), respectively. These scaled positive impulse values e-quate to 0.76, 1.02, 0.65, 0.66, 1.10, and 0.52 times equal amounts of TNT at the same scaled distances, respectively.

CONCLUSIONS

(1) Aluminum/potassium perchlorate (34/66% by weight) will mass detonate in charge weights of 50, 150, and 360 grams.

(2) The variations in the test results are due in part to the fact that as a pyrotechnic mixture, the material must transition from a deflagration to a detonation causing lower pressure and impulse at close-in scaled distances and higher values at the far-field scaled distances.

(3) To within limits of the experiment, the results of the aluminum/potassium perchlorate scales as a function of the cube root of the charge weight.

(4) Boron/calcium chromate (20/80% by weight) failed to mass detoante in any of the quantities tested.

Table 97. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for 150-g $Al/KClO_4$ Pyrotechnic Mixture.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	78.36	540.31	15.51	139.21	22.000	8.727	2.79	19.25	3.03	27.22
4.000	1.587	58.84	405.67	13.04	117.00	23.000	9.124	2.63	18.16	2.89	25.95
5.000	1.983	40.42	278.68	11.23	100.79	24.000	9.521	2.49	17.18	2.76	24.77
6.000	2.380	28.20	194.45	9.85	88.39	25.000	9.917	2.36	16.29	2.64	23.69
7.000	2.777	20.47	141.16	8.76	78.60	26.000	10.314	2.24	15.48	2.53	22.68
8.000	3.174	15.49	106.83	7.87	70.65	27.000	10.711	2.14	14.73	2.42	21.74
9.000	3.570	12.74	87.84	7.28	65.29	28.000	10.108	2.04	14.04	2.33	20.87
10.000	3.967	9.88	68.12	6.52	58.53	29.000	11.504	1.94	13.40	2.23	20.05
11.000	4.364	8.24	56.80	6.00	53.80	30.000	11.901	1.86	12.80	2.15	19.29
12.000	4.760	7.03	48.44	5.54	49.72	31.000	12.298	1.77	12.23	2.07	18.58
13.000	5.157	6.11	42.11	5.14	46.16	32.000	12.694	1.70	11.70	1.99	17.96
14.000	5.554	5.39	37.19	4.80	43.03	33.000	13.091	1.62	11.20	1.92	17.27
15.000	5.950	4.83	33.28	4.49	40.26	34.000	13.488	1.55	10.72	1.86	16.67
16.000	6.347	4.37	30.11	4.21	37.79	35.000	13.884	1.49	10.26	1.80	16.11
17.000	6.744	3.99	27.50	3.96	35.57	36.000	14.281	1.43	9.83	1.74	15.58
18.000	7.141	3.67	25.32	3.74	33.57	37.000	14.678	1.36	9.41	1.68	15.08
19.000	7.537	3.40	23.46	3.54	31.76	38.000	15.075	1.31	9.01	1.63	14.60
20.000	7.934	3.17	21.86	3.35	30.11	39.000	15.471	1.25	8.63	1.58	14.15
21.000	8.331	2.97	20.47	3.19	28.60	40.000	15.868	1.20	8.26	1.53	13.72

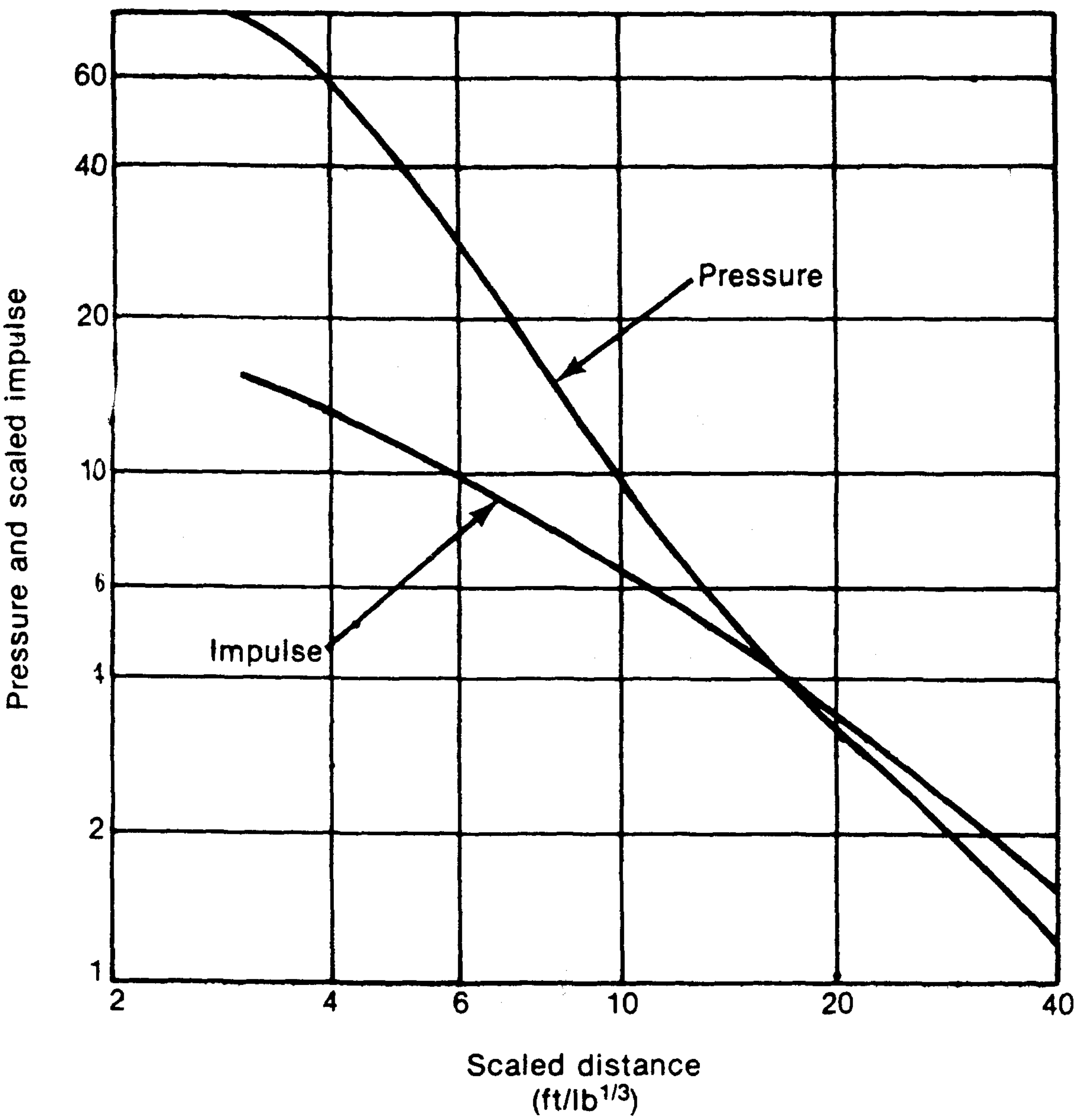


Figure 138. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for 150-g Al/$KClO_4$ Pyrotechnic Mixture.

Table 98. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for 360-g Al/$KClO_4$ Pyrotechnic Mixture.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	88.54	610.48	12.12	109.60	22.000	8.727	2.90	20.00	3.86	34.63
4.000	1.587	50.08	345.29	12.14	108.94	23.000	9.127	2.73	18.79	3.65	32.76
5.000	1.983	32.76	225.89	11.64	104.47	24.000	9.521	2.57	17.71	3.46	31.04
6.000	2.380	23.43	161.56	10.98	98.54	25.000	9.917	2.43	16.75	3.28	29.43
7.000	2.777	17.79	122.68	10.28	92.22	26.000	10.314	2.30	15.88	3.11	27.94
8.000	3.174	14.10	97.22	9.58	85.98	27.000	10.711	2.19	15.09	2.96	26.55
9.000	3.570	11.54	79.56	8.92	80.05	28.000	11.108	2.08	14.37	2.81	25.25
10.000	3.967	9.68	66.74	8.30	74.51	29.000	11.504	1.99	13.72	2.68	24.04
11.000	4.364	8.28	57.10	7.73	69.41	30.000	11.901	1.90	13.12	2.55	22.91
12.000	4.760	7.20	49.65	7.21	64.71	31.000	12.298	1.82	12.57	2.44	21.85
13.000	5.157	6.34	43.74	6.73	60.41	32.000	12.694	1.75	12.07	2.32	20.86
14.000	5.554	5.65	38.97	6.29	56.47	33.000	13.091	1.68	11.60	2.22	19.93
15.000	5.950	5.08	35.05	5.89	52.86	34.000	13.488	1.62	11.17	2.12	19.05
16.000	6.347	4.61	31.79	5.52	49.56	35.000	13.884	1.56	10.76	2.03	18.23
17.000	6.744	4.21	29.03	5.18	46.52	36.000	14.281	1.51	10.39	1.95	17.46
18.000	7.141	3.87	26.68	4.87	43.74	37.000	14.678	1.46	10.04	1.86	16.72
19.000	7.537	3.58	24.65	4.59	41.18	38.000	15.075	1.41	9.71	1.79	16.04
20.000	7.934	3.32	22.90	4.33	38.82	39.000	15.471	1.36	9.41	1.71	15.38
21.000	8.331	3.10	21.35	4.08	36.64	40.000	15.868	1.32	9.12	1.65	14.77

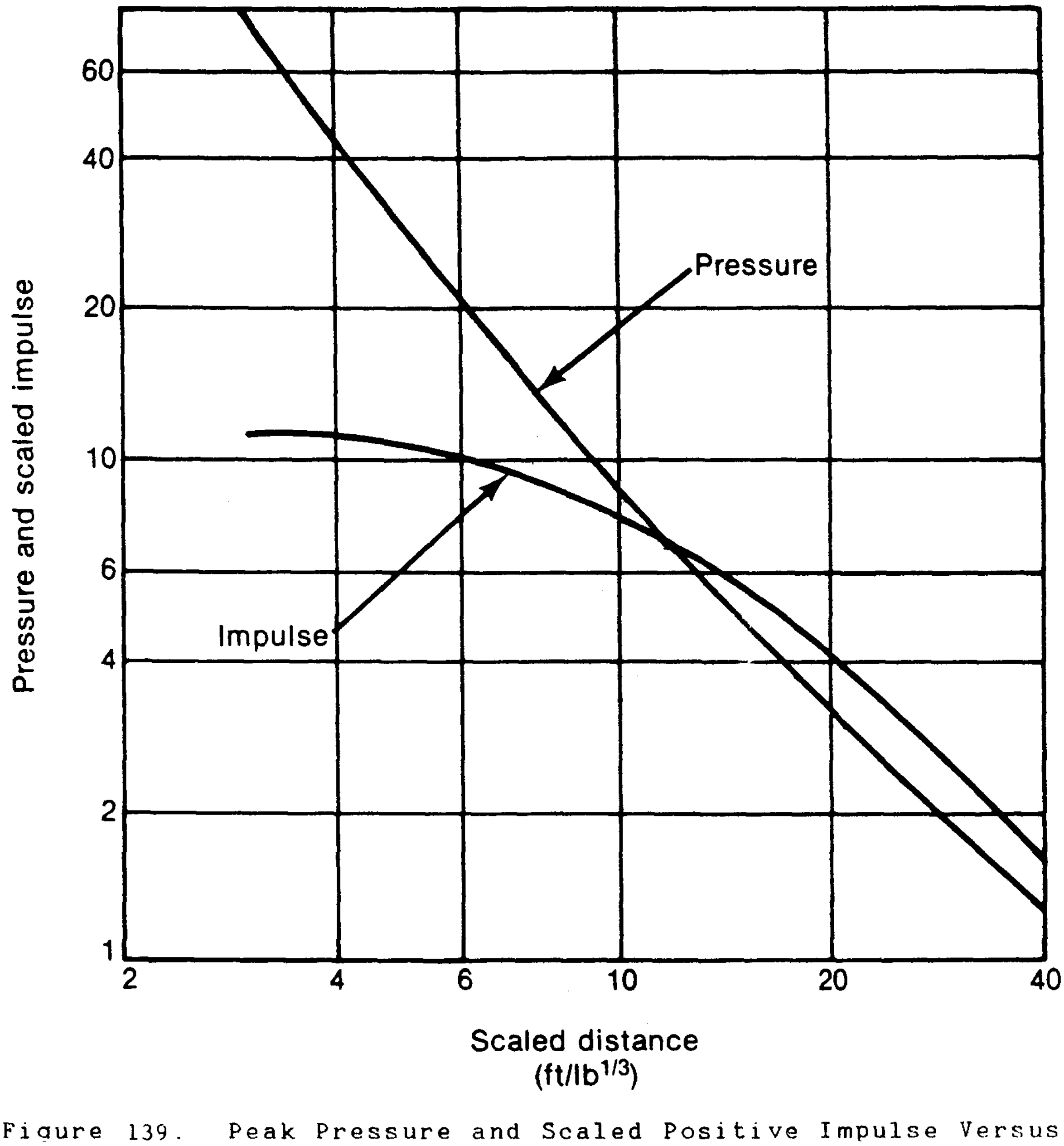


Figure 139. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for 360-g $Al/KClO_4$ Pyrotechnic Mixture.

Table 99. Summary of Results for Hemispherical Surface Bursts. Peak Pressure. and Scaled Positive Impulse for Combined Weights for $Al/KClO_4$.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	88.01	606.86	17.09	153.32	22.000	8.727	2.66	18.33	3.06	27.45
4.000	1.587	52.73	363.57	13.61	122.10	23.000	9.124	2.48	17.08	2.93	26.31
5.000	1.983	35.26	243.13	11.35	101.84	24.000	9.521	2.32	15.97	2.82	25.27
6.000	2.380	25.35	174.80	9.75	87.53	25.000	9.917	2.17	14.99	2.71	24.30
7.000	2.777	19.19	132.28	8.56	76.85	26.000	10.314	2.05	14.11	2.61	23.40
8.000	3.174	15.08	104.00	7.64	68.55	27.000	10.711	1.93	13.31	2.51	22.57
9.000	3.570	12.21	84.22	6.90	61.89	28.000	11.108	1.83	12.60	2.43	21.79
10.000	3.967	10.13	69.82	6.29	56.43	29.000	11.504	1.73	11.95	2.35	21.06
11.000	4.364	8.56	59.01	5.78	51.87	30.000	11.901	1.65	11.36	2.27	20.38
12.000	4.760	7.35	50.66	5.35	47.99	31.000	12.298	1.57	10.82	2.20	19.74
13.000	5.157	6.39	44.09	4.98	44.66	32.000	12.694	1.50	10.33	2.13	19.13
14.000	5.554	5.63	38.80	4.65	41.76	33.000	13.091	1.43	9.88	2.07	18.56
15.000	5.950	5.00	34.49	4.37	39.21	34.000	13.488	1.37	9.46	2.01	18.03
16.000	6.347	4.48	30.92	4.12	36.95	35.000	13.884	1.32	9.08	1.95	17.52
17.000	6.744	4.05	27.93	3.89	34.94	36.000	14.281	1.27	8.72	1.90	17.04
18.000	7.141	3.68	25.40	3.69	33.14	37.000	14.678	1.22	8.39	1.85	16.58
19.000	7.537	3.37	23.24	3.51	31.51	38.000	15.075	1.17	8.09	1.80	16.15
20.000	7.934	3.10	21.37	3.35	30.03	39.000	15.471	1.13	7.80	1.75	15.74
21.000	8.331	2.86	19.75	3.20	28.68	40.000	15.868	1.09	7.54	1.71	15.35

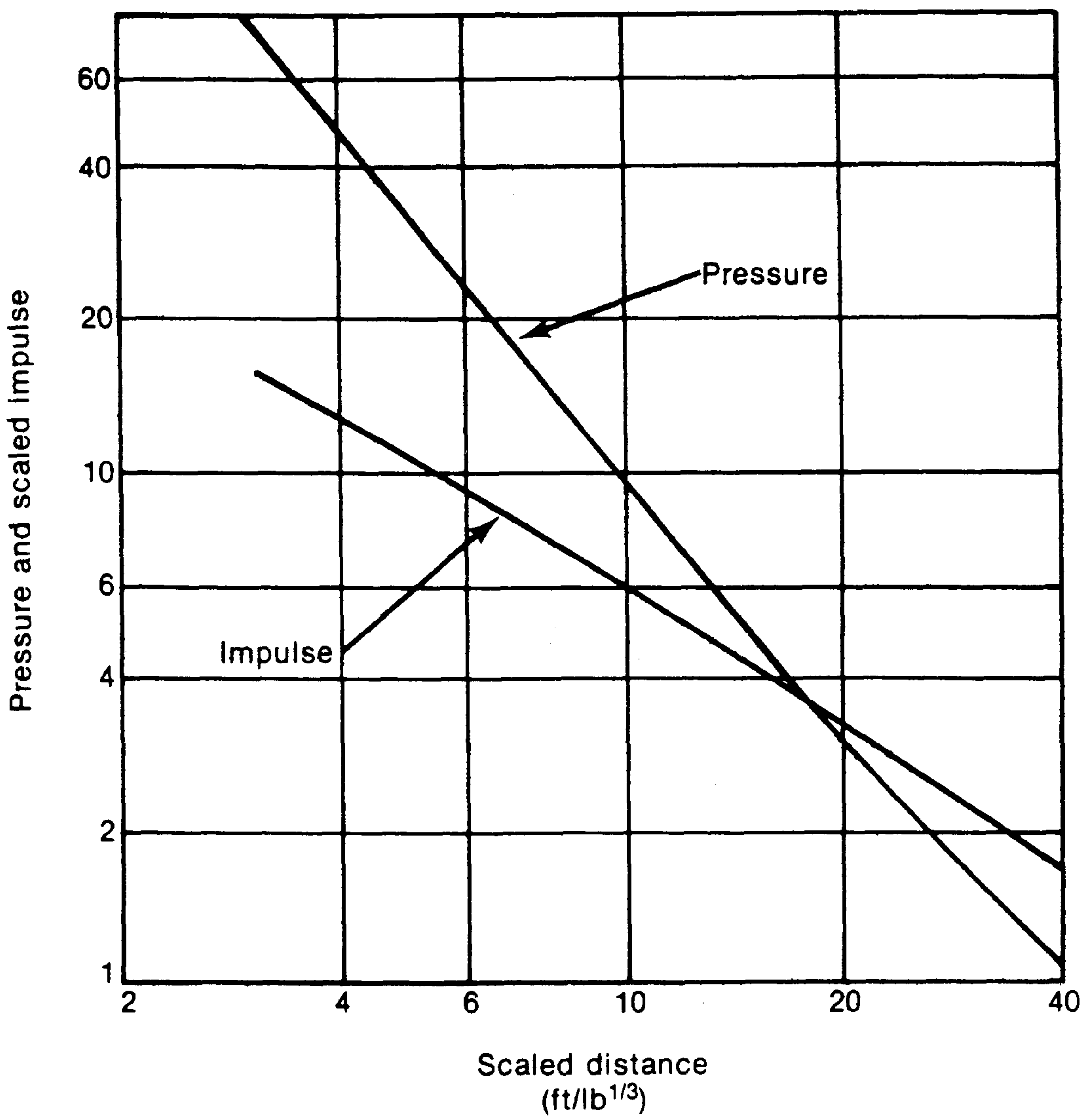


Figure 140. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for the Combined Weights for AL/$KClO_4$.

TNT EQUIVALENCY OF M49A1 TRIP FLARE MIXTURE, 105 mm ILLUMINANT MIXTURE AND FIRST FIRE MIXTURE [40]

OBJECTIVE

The primary objective of this program was to determine the maximum airblast output of three pyrotechnic mixtures and to compare these values to known characteristics of hemispherical TNT and determine the TNT equivalency.

MATERIALS

The M314A3 Illuminant Mixture consisted of magnesium/sodium nitrate/and laminac 4116 in 56/36/8% by weight respectively, The M49A1 Trip Flare Mixture consisted of magnesium/sodium nitrate/laminac 4116 in 54/36/10% by weight respectively. The First Fire Mixture Drawing No. 9251742 for the M314A3 mixture consisted of barium nitrate/silicon/ zirconium hydride/tetranitrocarbazole/laminac in 50/20/15/10/5% respectively.

TEST SETUP

A total of 87 tests were performed, of which 30 tests utilized M314A3 105 mm illuminant mixture, 28 tests M49A1 trip flare mixture and 29 tests 105 mm M314A3 first fire mixture . The M314A3 105 mm illuminant and the M49A1 mixture tests were conducted using 22.7 kg (50 lb) quantities and the 105 mm M314A3 first fire weighed 4.54 kg (10 lb). All test series siimulated in-process conditions using scaled models of mix/mullers or cardborad shipping drums.

The samples were ignited by a wide range of stimuli including squibs, blasting caps, and explosive boosters.

INSTRUMENTATION

RESULTS

The results of the 105 mm M314A3 Illuminant mixture tests are shown in Table 100 and Figure 141. The results of the M49A1 Trip Flare mixture are given in Table 101 and Figure 142. The results of the 105 mm M314A3 First Fire mixture are given in Table 102 and Figure 143.

DISCUSSION

Peak pressure values for the 105 mm M314A3 Illuminant mixture were less than expected at all scaled distances of the experiment. Peak pressure values were 382, 216, 121, 47, 13, and 3.4 kPa (55.34, 31.41 17.60, 6.75, 1.94, and 0.50 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 0.31, 0.36, 0.36, 0.41, 0.25, and 0.14 times equal amounts of TNT at the same scaled distances respectively. Scaled positive impulse values were less than expected at all scaled distances of the experiment. Scaled positive impulse values were 106.0, 79.5, 58.9, 35.3, 17.6, and 7.9 kPa-ms/kg$^{1/3}$ (11.82, 8.86, 6.56, 3.93, 1.96, and 0.88 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14 and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.42, 0.43, 0.43, 0.42, 0.32, and 0.36 times equal amounts of TNT at the same scaled distances, respectively.

Peak pressure values for the M49A1 Trip Flare mixture were less than expected at all scaled distances of the experiment. Peak pressure values were 501, 282, 157, 61, 18, and 5 kPa (72.69, 40.93, 22.84, 8.78, 2.59 and 0.70 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 0.46, 0.50, 0.50, 0.65, 0.49, and 0.31 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were lesss than expected at all scaled distances of the experiment. Scaled positive impulse values were 151.2, 116.4, 88.6, 77.7, 29.7, and 14.4 kPa-ms/kg$^{1/3}$ (16.85, 12.97, 9.88, 6.21, 3.31, and 1.60 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.76, 0.76, 0.77, 0.77, 0.67, and 0.69 times equal amounts of TNT at the same scaled distances, respectively.

Peak pressure values for the 105 mm M314A3 First Fire mixture were less than expected at all scaled distances of the experiment. Peak pressure values were 527, 273, 142, 51, 15, and 5 kPa (76.43, 39.53, 20.64, 7.46, 2.24, and 0.73 psi) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0, and 40.0 ft/lb$^{1/3}$), respectively. These pressure values equate to 0.48, 0.49, 0.48, 0.46, 0.37, and 0.33 times equal amounts of TNT at the same scaled distances, respectively. Scaled positive impulse values were lesss than expected at all scaled distances of the experiment. Scaled positive impulse values were 140.0, 105.5, 78.3, 47.2, 23.8, and 10.8, kPa-ms/kg$^{1/3}$ (15.63, 11.75, 8.73, 5.26, 2.65, and 1.20 psi-ms/lb$^{1/3}$) at scaled distances of 1.19, 1.59, 2.14, 3.57, 7.14, and 15.87 m/kg$^{1/3}$ (3.0, 4.0, 5.4, 9.0, 18.0 and 40.0 ft/lb$^{1/3}$), respectively. These scaled positive impulse values equate to 0.77, 0.70, 0.67, 0.53, 0.51, and 0.49 times equal amounts of TNT at the same scaled distances, respectively.

The M49A1 Trip Flare mixture highest TNT pressure equivalencies of the three mixtures tested. The M314A3 First Fire mixture had the highest impulse TNT equivalency. Both the 105 mm M314A3 Illuminant and First Fire mixture had roughly the same pressure equivalencies but their impulse equivalencies were different with the M314A3 First Fire being higher.

CONCLUSIONS

1. All three pyrotechnic mixtures evaluated indicated that they are capable of detonation when initiated by a strong shock wave.

2. TNT equivalencies exceeding 50% were obtained when the mixtures were initiated by an explosive booster greater than 2%.

3. The three pyrotechnic mixtures did not produce airblast overpressures when initiated by squibs, blasting caps, 2 ounces of black powder or open flame. Initiation by these means produced burning type reactions.

4. The 105 mm M314A3 first fire mixture test using a slow heat initiator indicated that a low order detonation may have occurred.

5. Confinement resulting from the mix/muller does not significantly affect the airblast output.

Table 100. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for 105 mm M314A3 Illuminant Mixture.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	55.34	381.59	11.82	106.07	22.000	8.727	1.37	9.42	1.60	14.40
4.000	1.587	31.41	216.60	8.86	79.50	23.000	9.124	1.27	8.73	1.53	13.77
5.000	1.983	20.40	140.64	7.08	63.57	24.000	9.521	1.18	8.11	1.47	13.20
6.000	2.380	14.40	99.30	5.90	52.95	25.000	9.917	1.10	7.56	1.41	12.67
7.000	2.777	10.77	74.24	5.06	45.37	26.000	10.314	1.03	7.07	1.36	12.18
8.000	3.174	8.39	57.85	4.42	39.69	27.000	10.711	0.96	6.63	1.31	11.73
9.000	3.570	6.75	46.51	3.93	35.27	28.000	11.108	0.90	6.24	1.26	11.31
10.000	3.967	5.56	38.33	3.54	31.74	29.000	11.504	0.85	5.88	1.22	10.92
11.000	4.364	4.67	32.21	3.21	28.84	30.000	11.901	0.80	5.55	1.18	10.55
12.000	4.760	3.99	27.51	2.95	26.44	31.000	12.298	0.76	5.25	1.14	10.21
13.000	5.157	3.45	23.82	2.72	24.40	32.000	12.694	0.72	4.93	1.10	9.89
14.000	5.554	3.02	20.85	2.52	22.65	33.000	13.091	0.69	4.73	1.07	9.59
15.000	5.950	2.67	18.44	2.35	21.14	34.000	13.488	0.65	4.50	1.04	9.31
16.000	6.347	2.39	16.45	2.21	19.81	35.000	13.884	0.62	4.28	1.01	9.04
17.000	6.744	2.14	14.78	2.08	18.65	36.000	14.281	0.59	4.09	0.98	8.79
18.000	7.141	1.94	13.36	1.96	17.61	37.000	14.678	0.57	3.91	0.95	8.55
19.000	7.537	1.76	12.16	1.86	16.68	38.000	15.075	0.54	3.74	0.93	8.33
20.000	7.934	1.61	11.12	1.77	15.84	39.000	15.471	0.52	3.58	0.90	8.11
21.000	8.331	1.48	10.12	1.68	15.09	40.000	15.868	0.50	3.43	0.88	7.91

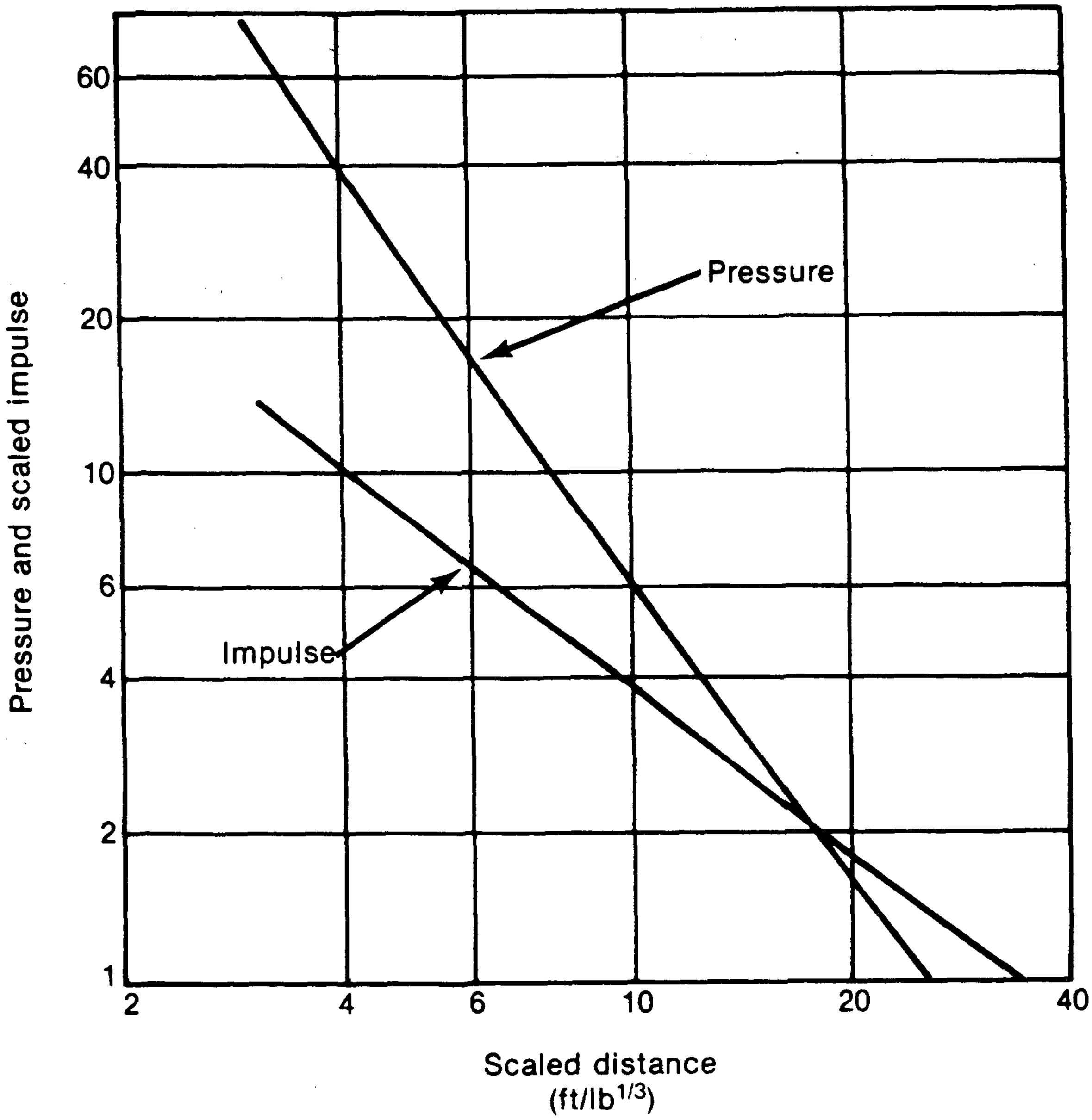


Figure 141. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for 105 mm M314A3 Illuminant Mixture.

Table 101. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for M49A1 Trip Flare Mixture.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	72.69	501.17	16.85	151.18	22.000	8.727	1.85	12.73	2.76	24.74
4.000	1.587	40.93	282.19	12.97	116.41	23.000	9.124	1.72	11.83	2.65	23.76
5.000	1.983	26.48	182.60	10.59	95.05	24.000	9.521	1.60	11.02	2.55	22.86
6.000	2.380	18.68	128.81	8.98	80.55	25.000	9.917	1.49	10.31	2.45	22.03
7.000	2.777	13.97	96.34	7.80	70.02	26.000	10.314	1.40	9.66	2.37	21.26
8.000	3.174	10.90	75.17	6.91	62.02	27.000	10.711	1.32	9.09	2.29	20.54
9.000	3.570	8.78	60.55	6.21	55.73	28.000	11.108	1.24	8.57	2.21	19.88
10.000	3.967	7.25	50.01	5.64	50.64	29.000	11.504	1.17	8.09	2.15	19.25
11.000	4.364	6.11	42.14	5.18	46.44	30.000	11.901	1.11	7.66	2.08	18.67
12.000	4.760	5.23	35.09	4.78	42.91	31.000	12.298	1.05	7.27	2.02	18.12
13.000	5.157	4.54	31.33	4.45	39.90	32.000	12.694	1.00	6.91	1.96	17.61
14.000	5.554	3.99	27.51	4.16	37.31	33.000	13.091	0.95	6.58	1.91	17.12
15.000	5.950	3.54	24.40	3.90	35.04	34.000	13.488	0.91	6.27	1.86	16.66
16.000	6.347	3.17	21.83	3.68	33.04	35.000	13.884	0.87	5.99	1.81	16.23
17.000	6.744	2.85	19.67	3.48	31.27	36.000	14.281	0.83	5.73	1.76	15.82
18.000	7.141	2.59	17.84	3.31	29.69	37.000	14.678	0.80	5.49	1.72	15.43
19.000	7.537	2.36	16.28	3.15	28.27	38.000	15.075	0.76	5.27	1.68	15.06
20.000	7.934	2.17	14.93	3.01	26.98	39.000	15.471	0.73	5.06	1.64	14.71
21.000	8.331	2.00	13.76	2.88	25.81	40.000	15.868	0.70	4.86	1.60	14.38

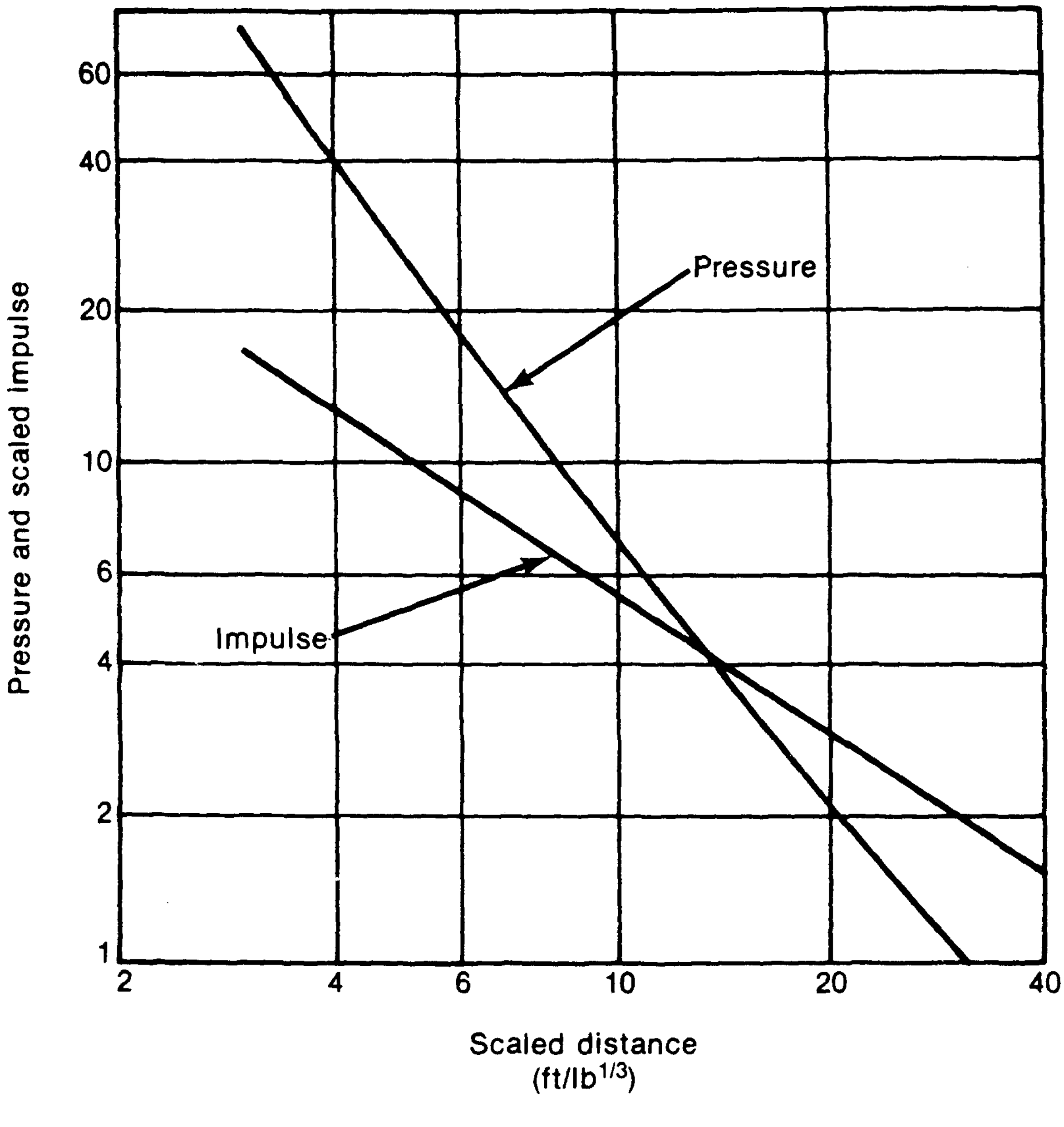


Figure 142. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for M49A1 Trip Flare Mixture.

Table 102. Summary of Results for Hemispherical Surface Bursts, Peak Pressure, and Scaled Positive Impulse for M314A3 First Fire Mixture.

Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$	Scaled Distance ft/lb	Scaled Distance m/kg	Pressure psi	Pressure kPa	Scaled Impulse $\frac{psi \cdot ms}{lb^{1/3}}$	Scaled Impulse $\frac{kPa \cdot ms}{kg^{1/3}}$
3.000	1.190	76.43	526.96	15.63	140.25	22.00	8.727	1.65	11.35	2.17	19.46
4.000	1.587	39.53	272.58	11.75	105.46	23.000	9.124	1.54	10.62	2.08	18.63
5.000	1.983	24.30	167.51	9.42	84.53	24.000	9.521	1.45	9.98	1.99	17.86
6.000	2.380	16.58	114.33	7.86	70.56	25.000	9.917	1.36	9.40	1.91	17.15
7.000	2.777	12.14	83.70	6.75	60.56	26.000	10.314	1.29	8.89	1.84	16.49
8.000	3.174	9.34	64.42	5.91	83.05	27.000	10.711	1.22	8.43	1.77	15.89
9.000	3.570	7.46	51.45	5.26	27.21	28.000	11.108	1.16	8.01	1.71	15.33
10.000	3.967	6.13	42.30	4.74	42.53	29.000	11.504	1.11	7.63	1.65	14.80
11.000	4.364	5.16	35.57	4.31	38.69	30.000	11.901	1.06	7.28	1.59	14.31
12.000	4.760	4.42	30.47	3.96	35.49	31.000	12.298	1.01	6.96	1.54	13.86
13.000	5.157	3.84	26.51	3.65	32.79	32.000	12.694	0.97	6.67	1.50	13.43
14.000	5.554	3.39	23.26	3.39	30.47	33.000	13.091	0.93	6.40	1.45	13.02
15.000	5.950	3.02	20.80	3.17	28.45	34.000	13.488	0.89	6.15	1.41	12.64
16.000	6.347	2.71	18.70	2.97	26.69	35.000	13.884	0.86	5.93	1.37	12.29
17.000	6.744	2.46	16.95	2.80	25.13	36.000	14.281	0.83	5.71	1.33	11.95
18.000	7.141	2.24	15.47	2.65	23.75	37.000	14.678	0.80	5.52	1.30	11.63
19.000	7.537	2.06	14.21	2.51	22.51	38.000	15.075	0.77	5.33	1.26	11.32
20.000	7.934	1.90	13.12	2.38	21.39	39.000	15.471	0.75	5.16	1.23	11.04
21.000	8.331	1.77	12.18	2.27	20.38	40.000	15.868	0.73	5.00	1.20	10.76

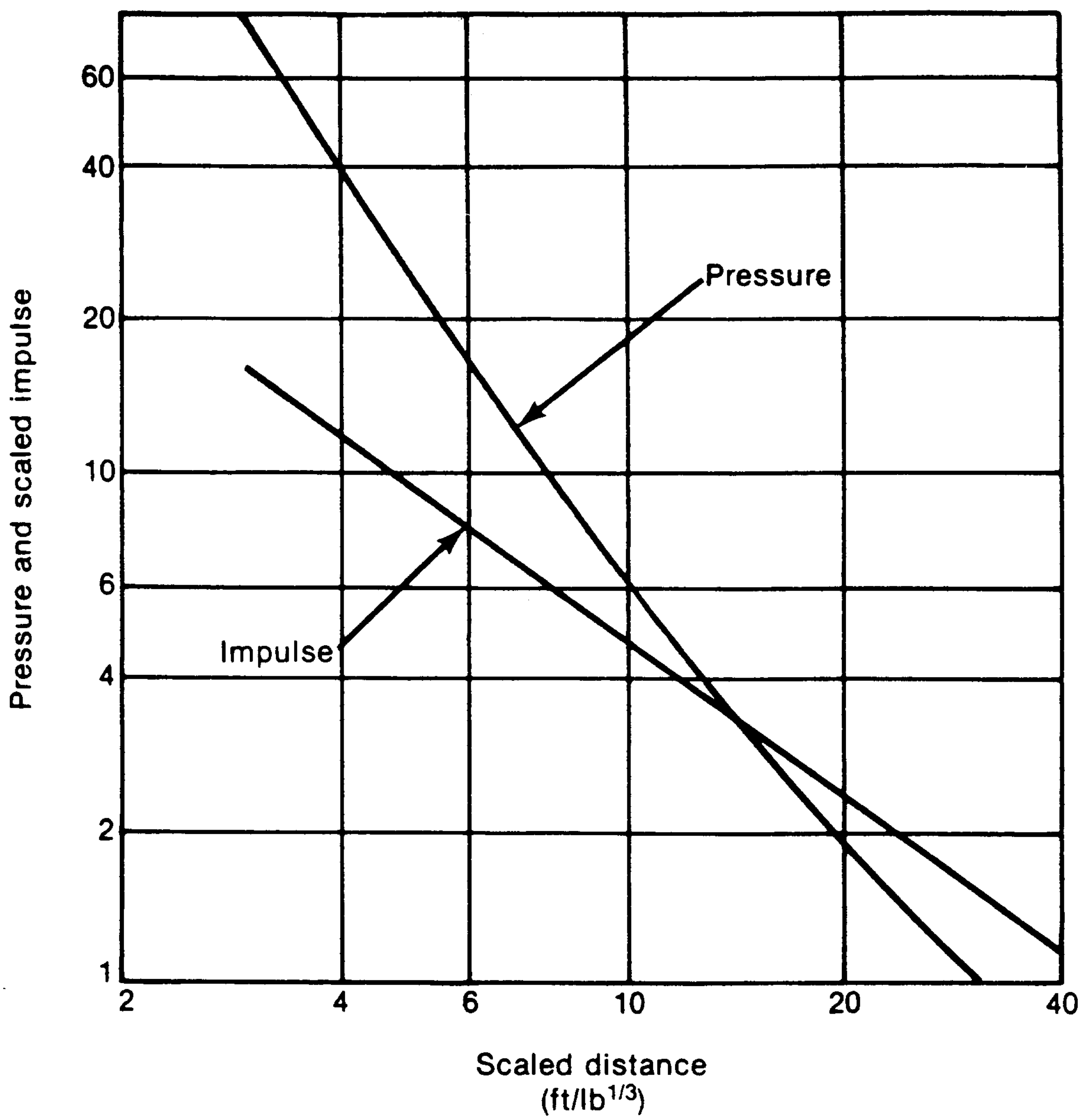


Figure 143. Peak Pressure and Scaled Positive Impulse Versus Scaled Distance for M314A3 First Fire Mixture.

SUMMARY OF PYROTECHNIC TNT EQUIVALENCY TESTS

TNT equivalency tests were conducted on nine pyrotechnic mixtures. Table 103 shows the results of TNT equivalency versus scaled distance and Table 104 is a summary of all of the pyrotechnic materials that have some form of TNT equivalency testing conducted on them but not necessarily as a part of this program.

The pyrotechnic mixtures which were subjected to TNT equivalency testing were: two primer mixtures, three tracer mixtures, two illuminants, first fire mixture, and a delay mixture. All mixtures were tested in a dried state in a fine granulation before the mixtures would have been consolidated into the end item. The obtained values then would represent the "worst-case" conditions found during manufacturing processing. Specific tests were conducted in simulated processing equipment.

The primer mixtures were binary mixtures consisting of potassium perchlorate/titanium subhydride and potassium perchlorate/aluminum. The boron/calcium chromate delay mixture would not detonate because this mixture is a gasless mixture. The potassium perchlorate/titanium subhydride and the potassium perchlorate/aluminum mixtures were gaseous and the TNT equivalency values were generally equal to or greater than 50%. The illuminant mixtures were ternary mixtures of sodium nitrate/magnesium/binder and or the addition of an intensifier for greater illumination. These mixtures are also gaseous and the TNT equivalency values ranged as high as 70%. The tracer mixtures had a much lower TNT equivalency values. The first fire mixture also had a low TNT equivalency value.

Several factors affect the TNT equivalency of the various pyrotechnic mixtures. The fuel/oxidizer ratio and the type of fuel and oxidizer used determine if the mixture will be gaseous or gasless. Gaseous type of mixtures will have a higher TNT equivalency value than a gasless type mixture. The particle size of both the fuel and oxidizer will also have a significant effect on the TNT equivalency value. Gaseous mixtures in an unconsolidated state will have higher values than when the mixture is consolidated. Pressure and impulse also varied with the geometry.

Booster charges used in the initation of the pyrotechnic mixtures were critical. Booster charges were necessary because under normal circumstances pyrotechnics are not considered as mass detonating material. The booster charge shape, standoff distance, and size were critical in order to obtain an explosion. The effect of the booster charge was factored out by an iterative process and the pressure and impule values reported are the contribution of the mixture.

It should be noted that only a small percentage of the current pyrotechnics being produced was subjected to any form of blast measurement. This is because pyrotechnics, by definition, are not considered as mass detonating material. However, historical evidence does indicate that strong deflagrations, explosions and even the possibility of mass detonation have occurred. Such testing is usually conducted only after an incident occurs. However, safety site plans require that pyrotechnic mixtures be considered as Class/Division 1.1 explosives. Designing the manufacturing facility to these standards is costly, particularly if the proposed pyrotechnic mixture is only 10% TNT equivalency to that of equal amounts of TNT. Additional testing should be conducted in this area of safety and plant modernization.

Table 103. Summary of Peak Pressure and Scaled Positiv

					P
				L/D	Z =
Test Materials	Physical Geometry	Characteristics	Configuration	Ratio (x:1)	P
R284 Tracer Mixture	Cylindrical	Dry Powder	Rubber Cylinder	--	25.10
	Cylindrical	Dry Powder	Aluminum Cylinder	--	19.90
I559 Igniter Mixture	Cylindrical	Dry Powder	Rubber Cylinder	--	20.10
	Cylindrical	Dry Powder	Aluminum Cylinder	--	17.2
I560 Sub-Igniter Mixture	Cylindrical	Dry Powder	Rubber Cylinder	--	24.10
	Cylindrical	Dry Powder	Aluminum Cylinder	--	19.34
Electric Primer Mixture	Cylindrical	Dry Powder	180 grams	--	78.36
	Cylindrical	Dry Powder	360 grams	--	88.46
Aluminum/Potassium Perchlorate	Cylindrical	Dry Powder	Combined Values	--	88.18
M314A3 Illuminant Mix	--	Dry Powder	Combined Values	--	55.34
M49A1 Trip Flare Mix	--	Dry Powder	Combined Values	--	72.69
M314A3 First Fire Mix	--	Dry Powder	Combined Values	--	74.71

.03. Summary of Peak Pressure and Scaled Positive Impulse for Bulk Pyrotechnic Mixture.

			Peak Pressure (psi) and Scaled Positive Impulse (psi r									
		L/D Ratio	Z = 3.0		Z = 4.0		Z = 5.4		Z = 9.0		Z = 1	
naracteristics	Configuration	(x:1)	P	I	P	I	P	I	P	I	P	-
:y Powder	Rubber Cylinder	--	25.10	6.04	21.60	6.78	10.90	5.65	4.89	3.25	1.33	1
:y Powder	Aluminum Cylinder	--	19.90	5.04	15.70	4.52	2.38	4.19	3.78	3.13	1.25	1
:y Powder	Rubber Cylinder	--	20.10	5.49	16.60	5.73	7.66	5.97	3.47	3.12	1.11	1
:y Powder	Aluminum Cylinder	--	17.2	6.59	11.60	4.93	5.13	3.90	2.40	2.48	0.78	1
ty Powder	Rubber Cylinder	--	24.10	7.66	19.90	7.04	9.60	6.86	4.69	4.08	1.73	2
ty Powder	Aluminum Cylinder	--	19.34	4.29	14.24	6.24	8.06	5.45	4.02	3.67	1.41	1
'y Powder	180 grams	--	78.36	14.33	58.85	15.13	34.83	8.79	12.12	5.89	3.64	4
'y Powder	360 grams	--	88.46	7.06	64.00	15.25	32.10	9.09	11.08	7.07	4.20	5
'y Powder	Combined Values	--	88.18	16.26	51.87	15.43	31.91	9.08	11.16	5.97	3.78	4
y Powder	Combined Values	--	55.34	11.82	31.41	8.86	17.60	6.56	6.75	3.93	1.94	1
y Powder	Combined Values	--	72.69	16.85	40.93	12.97	22.84	9.88	8.78	6.21	2.59	3
y Powder	Combined Values	--	74.71	15.73	40.43	11.91	21.57	9.46	6.01	4.69	1.91	2

'e Impulse for Bulk Pyrotechnic Mixture.

'eak Pressure (psi) and Scaled Positive Impulse (psi ms/lb$^{1/3}$)

3.0	Z = 4.0		Z = 5.4		Z = 9.0		Z = 18.0		Z = 40.0	
I	P	I	P	I	P	I	P	I	P	I
6.04	21.60	6.78	10.90	5.65	4.89	3.25	1.33	1.55	0.59	0.63
5.04	15.70	4.52	2.38	4.19	3.78	3.13	1.25	1.25	0.46	0.40
5.49	16.60	5.73	7.66	5.97	3.47	3.12	1.11	1.30	0.50	0.61
6.59	11.60	4.93	5.13	3.90	2.40	2.48	0.78	1.00	0.44	0.40
7.66	19.90	7.04	9.60	6.86	4.69	4.08	1.73	2.01	0.52	0.73
4.29	14.24	6.24	8.06	5.45	4.02	3.67	1.41	1.70	0.67	0.61
14.33	58.85	15.13	34.83	8.79	12.12	5.89	3.64	4.54	1.21	1.16
7.06	64.00	15.25	32.10	9.09	11.08	7.07	4.20	5.56	1.69	1.87
16.26	51.87	15.43	31.91	9.08	11.16	5.97	3.78	4.44	1.32	1.26
1.82	31.41	8.86	17.60	6.56	6.75	3.93	1.94	1.96	0.50	0.88
6.85	40.93	12.97	22.84	9.88	8.78	6.21	2.59	3.31	0.70	1.60
5.73	40.43	11.91	21.57	9.46	6.01	4.69	1.91	2.40	0.72	1.20

Table 104. Summary of Peak Pressure and Scaled Positive Impulse

Test Materials	Physical Geometry	Characteristics	Configuration	L/D Ratio (x:1)	Z P
R284 Tracer Mixture	Cylindrical	Dry Powder	Rubber Cylinder	--	0.05
	Cylindrical	Dry Powder	Aluminum Cylinder	--	0.04
I559 Igniter Mixture	Cylindrical	Dry Powder	Rubber Cylinder	--	0.03
	Cylindrical	Dry Powder	Aluminum Cylinder	--	0.04
I560 Sub-Igniter Mixture	Cylindrical	Dry Powder	Rubber Cylinder	--	0.04
	Cylindrical	Dry Powder	Aluminum Cylinder	--	0.04
Electric Primer Mixture	Cylindrical	Dry Powder	180 grams	--	0.48
	Cylindrical	Dry Powder	360 grams	--	0.57
Aluminum/Potassium Perchlorate	Cylindrical	Dry Powder	Combined Values	--	0.57
M314A3 Illuminant Mix	--	Dry Powder	Combined Values	--	0.31
M49A1 Trip Flare Mix	--	Dry Powder	Combined Values	--	0.46
M314A3 First Fire Mix	--	Dry Powder	Combined Values	--	0.48

Peak Pressure and Scaled Positive Impulse TNT Equivalency Value for Bulk Pyrotechnic Mixture.

teristics	Configuration	L/D Ratio (x:1)	Peak Pressure (psi) and Scaled Positive Impulse (psi									
			Z = 3.0		Z = 4.0		Z = 5.4		Z = 9.0		Z = 18.	
			P	I	P	I	P	I	P	I	P	I
der	Rubber Cylinder	--	0.05	0.12	0.15	0.25	0.14	0.27	0.17	0.22	0.06	0.
der	Aluminum Cylinder	--	0.04	0.09	0.08	0.11	0.06	0.15	0.09	0.20	0.05	0.
der	Rubber Cylinder	--	0.03	0.10	0.09	0.18	0.06	0.30	0.08	0.21	0.03	0.
der	Aluminum Cylinder	--	0.04	0.16	0.07	0.16	0.03	0.15	0.05	0.15	0.02	0.
der	Rubber Cylinder	--	0.04	0.20	0.13	0.26	0.11	0.38	0.16	0.33	0.15	0.
der	Aluminum Cylinder	--	0.04	0.06	0.07	0.19	0.07	0.22	0.09	0.24	0.07	0.
der	180 grams	--	0.48	0.56	0.79	1.14	0.82	0.68	1.07	0.64	1.11	1.
der	360 grams	--	0.57	0.22	0.84	1.02	0.82	0.01	0.92	0.75	1.42	1.
der	Combined Values	--	0.57	0.86	0.66	1.07	0.79	0.65	0.92	0.68	1.18	1.
der	Combined Values	--	0.31	0.42	0.36	0.43	0.36	0.43	0.41	0.42	0.25	0.
der	Combined Values	--	0.46	[illegible]	0.50	0.76	[illegible]	0.77	0.65	0.77	[illegible]	0.6
der	Combined Values	--	0.48	0.77	0.49	0.70	0.48	0.67	0.46	0.53	0.37	0.

r Bulk Pyrotechnic Mixture.

d Scaled Positive Impulse (psi ms/lb$^{1/3}$)							
Z = 5.4		Z = 9.0		Z = 18.0		Z = 40.0	
P	I	P	I	P	I	P	I
.14	0.27	0.17	0.22	0.06	0.19	0.14	0.15
.06	0.15	0.09	0.20	0.05	0.13	0.06	0.07
.06	0.30	0.08	0.21	0.03	0.14	0.08	0.14
.03	0.15	0.05	0.15	0.02	0.10	0.08	0.08
.11	0.38	0.16	0.33	0.15	0.30	0.09	0.20
.07	0.22	0.09	0.24	0.07	0.20	0.16	0.13
.82	0.68	1.07	0.64	1.11	1.11	1.07	0.52
.82	0.01	0.92	0.75	1.42	1.42	2.22	0.58
.79	0.65	0.92	0.68	1.18	1.07	1.35	0.45
.36	0.43	0.41	0.42	0.25	0.32	0.14	0.36
[illegible]	0.77	0.65	0.77	[illegible]	0.67	0.31	[illegible] .69
.48	0.67	0.46	0.53	0.37	0.51	0.33	0.49

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APPENDIX A

DATA ACQUISITION PROGRAM

APPENDIX A

DATA ACQUISITION PROGRAM

```
1  GO TO 100
4  RMOVE 0,1
5  RETURN
8  MOVE -10, 0
9  RETURN
12  RMOVE 10, 0
13  RETURN
20  GO TO 600
24  RMOVE 0, -1
25  RETURN
36  GO TO 700
37  RETURN
40  GO TO 560
44  GO TO 545
100  REM
110  REM
120  REM
130  REM
140  REM
150  REM
160  REM
170  REM
180  REM
190  REM
200  REM
210  REM
220  INIT
230  I1=0
240  X=0
250  DIM Z(20)
260  PRINT "TEST INFORMATION??"
270  INPUT Q$
280  PRINT "TEST NUMBER [SPACE] DATE??"
290  INPUT T$
300  PRINT "CHANNEL NUMBER [SPACE] [T FOR TAPE]??"
310  INPUT C$
320  PRINT "8100 NUMBER?"
330  INPUT N$
340  PRINT "81000 INPUT RANGE?"
350  INPUT R$
360  PRINT "SAMPLE INTERVAL IN MICROSECONDS?"
370  INPUT S1
380  FOR I=1 TO 20
390  RBTYE Z(1)
400  NEXT I
410  Z1=SUM(Z)/20
420  PAGE
430  VIEWPORT 10,130,15,100
440  WINDOW 0,2000,-20,240
```

THIS PROGRAM PLOTS A GRAPH OF BIOMATION OUTPUT AND CALCULATES THE TOTAL IMPULSE UPON A "SRQ" SIGNAL. THE PRESSURE IS PLOTTED AS WORDS VS. TIME, AND THE IMPULSE IS GIVEN AS WORD*TIME.

THE GRAPH UNITS ARE 20 WORDS (Y-AXIS) VS. 100 SAMPLE INTERVALS (X-AXIS). THE Y-AXIS EXTENDS FROM -20 TO +235 WORDS, WITH THE BOTTOM LINE AS ZERO. THE Z-AXIS READS FROM ZERO TO 2000 SAMPLE INTERVALS.

THE PROGRAM AVERAGES THE FIRST 20 WORDS TO CALCULATE ZERO.

```
450  FOR J=0 to 2000 STEP 100
460  AXIS, 0,0,J,J/5
470  NEXT J
480  MOVE 0,0
485  FOR C=1 TO 1
500  FOR I=1 TO 2000
510  RBYTE X
520  DRAW I,X-Z1
530  I1=I1+(X-Z1)*1.0E-3*S1
535  SET KEY
540  NEXT I
545  REM TO CLEAR FOR LOOP
549  NEXT C
550  GO TO 600
560  PRINT USING 570: "*",I1
570  IMAGE "K",1A,KKKKKHHHH",5D.2D
580  MOVE I,X-Z1
590  RETURN
600  MOVE 0,0
610  PRINT USING 620:"TEST...",Q$,"TEST NUMBER AND DATE...",T$
620  IMAGE "HHHJJJJ",7A,16A,4X,23A,18A
630  PRINT USING 640: "CHANNEL...",C$,"8100...",N$, "RANGE+/-",R$,"V.F.S."
640  IMAGE 10A,1X,4A,8X,7A,1X,3A,8X,9A,1X,3A,1X,6A
650  PRINT USING 660:"MSEC PER BLOCK=",0.1*S1,"WORDS PER BLOCK=20"
660  IMAGE 15A,2X,4D.3D,8X,19A
670  END
700  GIN K,L
710  RDRAW 200,0
720  PRINT USING 730:L
730  IMAGE 3D.1D
740  MOVE I,X-Z1
750  RETURN
```

APPENDIX B

DATA REDUCTION PROGRAM

APPENDIX B

DATA REDUCTION PROGRAM

B.1 SYSTEM OVERVIEW

One run of the system processes a set of measurements of peak pressure and positive impulse taken in explosive tests of a particular material in a specific configuration, for one sample weight/booster weight combination, and produces tabular and graphic output. The following calculations are performed (each is described in a major subsection of Section B.2):

1. At each of several ranges, TNT pressure and impulse equivalencies are calculated from measured values of pressure and impulse. Means and standard deviations are calculated for pressure, scaled impulse, pressure equivalency, and impulse equivalency.

2. The means are taken as representative values of their respective physical quantities, and the standard deviations are interpreted as measurement uncertainties. Smoothed versions of the four quantities versus scaled distance are obtained from polynomial curve fits to the means.

3. The results of the curve fits are used to produce plots. Pressure and scaled impulse versus scaled distance appear on one plot, pressure and impulse equivalency versus scaled distance on another. The "points" used to obtain the fits (the mean values) are also plotted.

4. The fits to pressure and scaled impulse are used to generate tabulations of these quantities, at 0.2 ft/lb$^{1/3}$ intervals, over the range of 3 to 40 ft/lb$^{1/3}$.

Figure B.1 shows the logic flow executed by the program in performing these calculations.

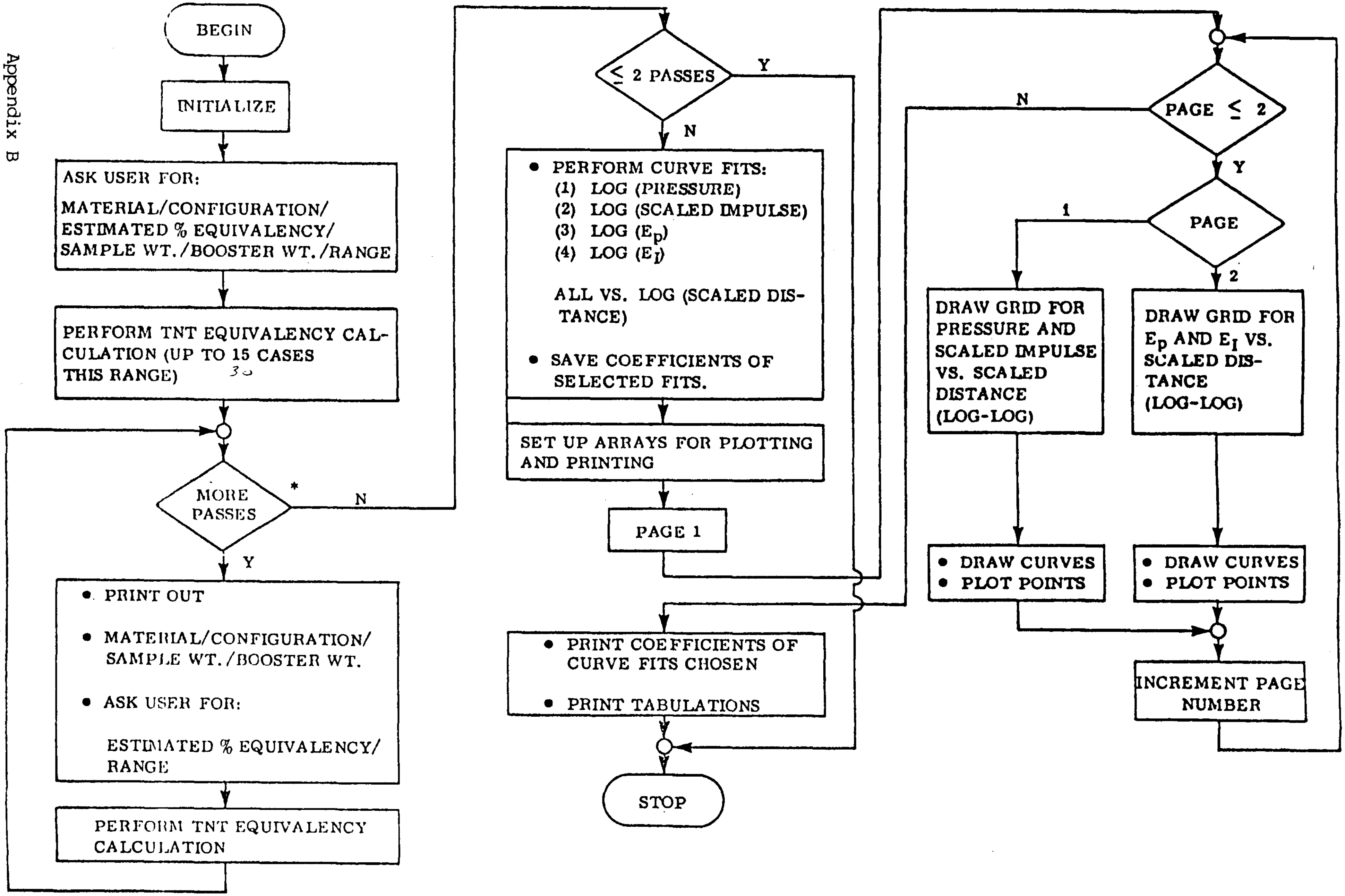
B.2 MAJOR SUBSYSTEMS

B.2.1 <u>TNT Equivalency Calculation</u>

The TNT equivalency E of the weight W of explosive is defined as

$$E = W_{TNT}/W, \tag{B.1}$$

where W_{TNT} is the weight of the quantity of TNT that produces the same effect (peak pressure or impulse) at an equal range R. For the present discussion, let M stand for either pressure or impulse. W_{TNT} can be found from a graph of M versus scaled distance,



*Program asks user; 12 passes maximum.

Figure B.1. TNT Equivalency Program Top-Level Logic Flow.

$$\lambda_{TNT} = R/W_{TNT}^{1/3}, \tag{B.2}$$

for TNT. However, the calculation does not simply consist of determining W_{TNT} graphically using the measured value of M and evaluatinG Equation (B.1). The reason is that the explosive charge is detonated with a "booster," so the measured M included a contribution from the booster as well as from the test sample. In order to calculate the TNT equivalency of the sample only, it is necessary to account for the contribution from the booster, which in general has a different TNT equivalency from the sample.

The TNT equivalency of the booster is 1.25, so the correct total weight to use as the denominator in Equation (B.1) is

$$W_{TOT} = W_S + 1.25\ W_B/E, \tag{B.3}$$

where W_S is the weight of the sample and W_B that of the booster. Equation (B.3) may be substituted into Equation (B.1), yielding

$$E = W_{TNT}/(W_S + 1.25\ W_B/E), \tag{B.4}$$

which can be solved for E:

$$E = (W_{TNT} - 1.25\ W_B)/W_S \tag{B.5}$$

Equation (B.2) may then be used to eliminate W_{TNT}:

$$E = \left\{\left(R/\ _{TNT}\right)^3 - 1.25\ W_B\right\}/W\ _S \tag{B.6}$$

For the calculation of pressure equivalency, there is no further difficulty. The analytical approximation (curve fit) used for the TNT pressure/scaled distance curve is a function of pressure alone. Consequently, Equation (B.6) may be used to calculate TNT pressure equivalency entirely in terms of measured quantities, by using the aforementioned curve fit to give λ_{TNT} in terms of the measured pressure. However, the analogous curve fit to the TNT impulse/scaled distance curve also involves E, in a relatively complicated way. The method of handling the impulse equivalency calculation will be discussed below.

Equations (B.1) and (B.3) can be combined so as to eliminate the explicit E dependence, yielding

$$W_{TOT} = W_W + 1.25\ W_B/(W_{TNT}/W_{TOT}) \tag{B.7}$$

This equation is of the form

$$x = f(x), \tag{B.8}$$

where $x = W_{TOT}$. It is a general result of numerical analysis that equations of this type can be solved in some cases by guessing an initial value x_o and using the iterative procedure

$$x_{i+1} = f(x_i) \tag{B.9}$$

Convergence is guaranteed when the conditions[1]

$$|f'(x)| \leq q < 1 \quad \text{for} \quad a \leq x \leq b \tag{B.10a}$$

$$a \leq x_o \pm |f(x_o) - x_o|/(1-q) \leq b \tag{B.10b}$$

are satisfied, where

$$a \leq x \leq b. \tag{B.10c}$$

The application of these conditions to Equation (B.7) shows that the above iterative procedure always converges to the correct solution when the "first guess" W_o satisfies $W_o \geq 1/2W_{TOT}$. The computer programs uses $W_o = W_S$, which should be large enough unless E is so small that the second term in Equation (B.3) dominates the first.

It should be noted that the substitution

$$W_{TNT}/W_{TOT} = (\lambda_{TOT}/\lambda_{TNT})^3 \tag{B.11}$$

can be made, where λ_{TOT} is given by a relation that is similar to Equation (B.2) but involves W_{TOT}. The iterative procedure used in the program is:

Step 1. $i = 0$. Set $W_{TOT(i)} = W_{TOT(0)} = W_S$. Give $E_i = E_0$ some value.

Step 2. Calculate $_{TOT(i)} = R/W^{1/3}_{TOT(i)}$.

Step 3. Obtain λ_{TNT} from measured impulse via a curve fit (using E_i).

Step 4. Calculate $E_{i+i} = (\lambda_{TOT(i)}/\lambda_{TNT})^3$.

Step 5. Calculate $W_{TOT(i+i)} = W_S + 1.25\ W_B/E_{i+i}$.

Step 6. Test converge (program checks $|E_{i+i} - E_i|$).

If no convergence

Then increment i and go to step 2, else exit loop.

The desired quantity, E, is calculated as a byproduct of this calculation.

Pressure equivalency is calculated directly from Equation (B.6). Impulse equivalency is obtained by the above iterative procedure. At each range, sample means and standard deviations are calculated for pressure, scaled impulse, pressure equivalency, and impulse equivalency using standard formulas.[2]

B.2.2 Polynomial Curve Fits

Polynomial curve fits are made to log y versus log (scaled distance), where "y" represents the mean value of pressure, scaled impulse, pressure equivalency, and impulse equivalency, respectively. For each, fits are made for degree 1 through degree N - 2 (but limited to 10 coefficients), where N is the number of data points (i.e., the number of scaled distances), and a statistical test is used to select the appropriate fit.

First the fitting procedure will be described. Then the procedure for selecting the degree of fit will be outlined.

Suppose N observations are made of some "observable" y, assumed to have the form

$$y(x) = \sum_{k=1}^{n} a_k f_k(x), \ n < N \tag{B.12}$$

where the a_k are constants and the $f_k(x)$ are any suitable functions. When each $f_k(x)$ is a power of x, a polynomial expansion of y is the result. Matrix notation affords a simplification of Equation (B.12). Let $\underline{a}$ be the vector whose components are a_k and let $\underline{f}$ be the vector whose components are $f_k(x)$. Then Equation (B.12) can be written

$$y(x) = \underline{f}'\underline{a} \tag{B.13}$$

where $\underline{f}'$ is the transpose of $\underline{f}$.

There is one such equation for each observation. The index i, labeling observations (i = 1, 2, ..., N), may be regarded as a subscript of x. It is convenient to work simultaneously with the entire collection of observations. This is accomplished by constructing the vector $\underline{Y}$ whose components are the observations $y(x_i)$ and the matrix F whose rows are $\underline{f}^T(x_i)$.

Then the collection of equations can be written

Let "^" over a quantity denote an estimate of the quantity. The problem here is to obtain a "best" estimate of $\hat{\underline{a}}$ of the vector of parameters. This, in turn, gives a "best" estimate of the observation vector:

$$\hat{\underline{Y}} = F\ \hat{\underline{a}} \qquad \text{(B.15)}$$

The generalized-least-squares interpretation of the "best" estimate $\hat{\underline{a}}$ is that which minimizes

$$Q = (\underline{Y} - \hat{Y})'\ W\ (\underline{Y} - \hat{Y}) \qquad \text{(B.16)}$$

where W is a matrix whose diagonal elements are the weights of each observation and whose off-diagonal elements are zero.

The result of setting

$$dQ\ /\ d\hat{\underline{a}} = 0 \qquad \text{(B.17)}$$

where the vector derivative implies the scalar product by a vector operator whose components are $\Upsilon/\Upsilon\hat{a}_k$, is

$$\underline{a} = [F'\ W\ F]^{-1}\ F'\ W\underline{Y} \qquad \text{(B.18)}$$

This is the result of solving the "normal equation"

$$[F'\ W\ F]\ \hat{\underline{a}} = F'\ W\underline{Y} \qquad \text{(B.19)}$$

which results from Equation (B.17). The sign of the second derivative shows that $\hat{\underline{a}}$ given by Equation (B.18) minimizes Q. The components of the parameter vector $\hat{\underline{a}}$, for the case of polynomial fitting, are simply the polynomial coefficients.

It is clear that if some observations are more uncertain or unreliable than others, the former observations should be given less weight in the fitting process than the latter. In fact, it can be shown that the appropriate choice for the weight of each observation is the reciprocal of the square of its measurement uncertainty. The standard deviation is an estimate of that uncertainty. (The above discussion has assumed that the observations are uncorrelated. In general, the inverse of the covariance matrix is the appropriate weighting matrix.)

In the present case the standard deviations obtained by the program refer to the physical quantities, while the fits are made to their logarithms. Certainly some adjustment must be made. The appropriate transformation to apply to the standard deviations when fitting log y instead of y is

$$\sigma \rightarrow \sigma/(y\ \mathrm{Ln}\ 10) \qquad \text{(B.20)}$$

This is a special case of the following: 9 If a random variable x has an error ε, then the error δ in $z = f(x)$ is given by

$$\delta = (df(x)/dx) \cdot \varepsilon \tag{B.21}$$

[2].

The choice of the degree of fit is made by an analysis of variance.[2] A sequence of tests is performed, comparing each degree of fit with one degree lower. (Degree 1 is compared with a constant, the mean of the observations.) In each case the null hypothesis is that adding an extra term makes no significant difference. The statistical tests are made at a 95% confidence level.

B.2.3 Plots

Two graphs are produced by the program. Each of them contains two curves, obtained from the polynomial fits, and the associated data points (mean values). The first shows peak pressure and scaled impulse versus scaled distance. The second shows pressure and impulse equivalency versus scaled distance. Both are log-log plots.

The ordinates on both graphs are the same. The range of scaled distance values is 2 to 40 $ft/lb^{1/3}$. Tic marks are also drawn in both the upper and lower margins to designate 5.4 and 18 $ft/lb^{1/3}$. The y-axis scales are determined by the true minimum and maximum values of the data to be plotted, and rounded to "nice" values. Automatic scaling is accomplished. Grid lines are drawn and "tagged" with numerical values, the axes are labeled to identify the physical quantities plotted, and titles are printed.

Curves are drawn to display the smoothed functions obtained by the polynomial curve fits. The curves plotted are log (y-value) versus log (scaled distance), where "y-value" represents pressure, scaled impulse, pressure equivalency, and impulse equivalency. (The numerical axis labels give the values of the physical quantities rather than their logarithms.) Triangles are used to plot the mean values for the first and third of these, while squares are used for the second and fourth.

A sample of the plots produced by this program is shown in Section B.5.

B.2.4 Tabulations

Two of the four polynomial curve fits are used to generate tabulations. Values of pressure and scaled impulse are tabulated for scaled distances over the range 3 to 40 $ft/lb^{1/3}$, at intervals of 0.2 $ft/lb^{1/3}$. Scaled distance, pressure, and scaled impulse are tabulated in both British and metric units. The tabulation occupies several pages, each of which has a complete heading.

B.3 PROGRAM OPERATION

Two types of user action are necessary to run this program: entering data, and resuming execution after the program pauses to allow the contents of the screen to be printed. Both will be explained below.

In the first phase of program operation, one or more "passes" are performed to calculate TNT equivalencies from experimental measurements. First the program asks for the following information: name of (explosive or pyrotechnic) material, configuration, approximate percent equivalency, sample weight, booster weight, and range. After the user enters these quantities the program asks for (measured) values of pressure and impulse; up to 15 "cases" may be entered. This phase of data entry is terminated by entering a pair of zeros (0,0). An exception to this procedure occurs when there are 15 cases; data entry is automatically terminated after entry of the 15th pair of numbers.

Next the program performs TNT equivalency calculations, as described in Section B.2.1, and displays the results. After this message

MORE PASSES (Y/N)?

is displayed. If the response is Y then the program displays the name of the material, the configuration, and the sample and booster weights. The user should then enter the approximate percent equivalency, the range, and the associated values of pressure and impulse, as before. The TNT equivalency calculation is performed and the question

MORE PASSES (Y/N)?

is asked again.

This cycle is repeated until the answer to the question is N or until 12 passes (the program limit) have been entered. In case there are no more than two passes, the program is then finished. If more than two passes are entered, then the program next performs the other calculations described in the preceding sections.

The program pauses a number of places, in order to allow the user to make a hard copy of the contents of the screen, if desired. At these points the bell is rung to alert the user. It is merely necessary to press the RETURN key to resume execution. The program pauses:

1. After each set of data is entered.

2. After each "pass" of TNT equivalency calculations.

3. After each curve fit.

4. After each analysis of variance.

5. After each page of plots.

6. After the coefficients of the chosen curve fits are displayed.

7. After each page of tabulations.

B.4 PROGRAM DOCUMENTATION

B.4.1 Program Variables

Following is a list of the names of program variables and their descriptions. Arrays are shown subscripted; the subscripts are the array dimensions. The term "working variable" refers to an intermediate variable in a calculation, where further description would be difficult without a detailed explanation of the algorithm.

Name	Description
A(F1,F1)	Normal matrix for curve fits
A1	Coefficient for curve fit to pressure versus TNT scaled distance
A2	Coefficient for curve fit to scaled impulse versus TNT scaled distance
B(F1)	Right-hand side of curve fit normal equation
B1	See A1
B2	See A2
B3	Working variable
B$(1)	Work array (to print y axis labels)
C(54)	Coefficients for all fits to a data set
C1	Maximum number of cases per pass (15)
C9	ln(10)
C$(30)	Configuration
D(F1)	Partial derivatives of model w.r.t. fit parameters
D1	(Value of) determinant of normal matrix
E1(C1)	Pressure equivalencies
E2(C1)	Impulse equivalencies
E5	Approximate percent equivalency
F	X scale factor for curve fits/number of degrees of freedom for F test
F0(3)	British-metric conversion factors
F1	Maximum number of fit parameters (10)
F5(4)	Degrees of fits that are chosen
F9	Degree of fit chosen by test
G1	Loop index
G2	Loop index
H	Working variable

Name	Description
H1(F1)	Work array for matrix inversion routine
H2	Working variable
H3	Working variable
H4	Working variable
H5	Working variable
H6	Working variable
H7	Working variable
H8	Working variable
H9	Working variable
I	Loop index
I1(C1)	Impulses/scaled impulses
I2	Working variable
I3	Working variable
J	Loop index/working variable
J0	Offset in C array for a set of coefficients
J1(4,0)	y values for plots
J5(0)	x values for plots
K	Loop index
K1	Degree of fit
K2	"Old" estimate of impulse equivalency
K3	Convergence test quantity for impulse equivalency calculation
L(13)	Axis label values
L1	Loop index
L2	Loop index/working variable
L3	Loop index/working variable
L9	Boolean flag/working variable

Name	Description
M	Loop index
M1	Highest degree of fit to be attempted +1
M$(20)	Material
N	Loop index
N1	Number of passes/number of data points for fits
N2	Number of cases per pass
O	Number of points for plots and tabulations (186)
O1	Working variable
O2	Working variable
O3	Working variable
O4	Working variable
O5	Working variable
O6	Working variable
O7	Working variable
O8	Working variable
P(C1)	Pressures
PO(6)	Values printed in one line of tabulations
P1	Maximum number of passes (12)
P$(100)	Left halves of 4 titles for fit results
Q1(4,P1)	Means
Q2(4,P1)	Standard deviations
Q$(24)	Right half of titles for fit results
R(P1)	Variances after different degrees of fit
R1(F1)	Variances of terms
R2	Range for one pass
R$(25)	Working array to hold left half of title to print (during fitting)

Name	Description
S1	Loop index
S2(P1)	Uncertainties for curve fits
S3	Working variable (index of a fit coefficient)
T	Length of tic marks on x axis
T1	Flag that indicates whether test has chosen a degree of fit
T$(43)	Title for first page of plots
U1(4,F1)	Coefficients of fits that are chosen
U$(55)	Title for second page of plots
V1(F1)	Variance ratios
V2(F1)	5% F levels
V%(55)	Array to hold plot titles for printing
W(P1)	Least squares weighting factors
W1	Sample weight
W2	Equivalent total charge weight (sample + booster)
W3	Booster weight
W$(27)	Array to hold y axis labels for printing
X	Plot lower bound
X1(P1)	x values for curve fits
X3(P1)	Scaled x values
X4	x lower limit (plotting)
X5	x upper limit (plotting)
X$(28)	x axis label
Y	Plot upper bound
Y2(P1)	y values for curve fits
Y3	Value calculated from polynomial model
Y4	y lower limit (plotting)

Name	Description
Y5	y upper limit (plotting)
Y$(27)	y axis label for first page of plots
Z(P1)	Scaled distances
Z1	Accumulator for variance calculation/working variable
Z2	Pressure scaled distance/accumulator for variance calculation/ working variable
Z3	TNT pressure scaled distance/accumulator for variance calculation
Z4	TNT impulse scaled distance/single scaled x value
Z5	Approximation to TNT impulse scaled distance
Z$(23)	y axis label for second page of plots

B.4.2. Program Listing

A complete listing of the BASIC program follows this page.

B.5 PLOT SAMPLE PRODUCED BY THIS PROGRAM

```
100  REM TNT EQUIVALENCY CALCULATION FOR MULTIPLE PASSES WITH
110  REM DATA SMOOTHING, PLOTTING, AND TABULATIONS.
120  INIT
130  REM C1 = MAXIMUM NUMBER OF CASES PER PASS.
140  C1=30
150  DIM P(C1),I1(C1),E1(C1),E2(C1),W5(C1),R9(C1),W6(C1)
160  REM P1 = MAXIMUM NUMBER OF PASSES.
170  P1=6
180  DIM Q1(4,P1),Q2(4,P1)
190  DIM X1(P1),X3(P1),Y2(P1),S2(P1),W(P1),R(P1),Z(P1),
200  REM F1 = MAXIMUM NUMBER OF FIT PARAMETERS.
210  F1=10
220  DIM A(F1,F1),B(F1),D(F1),R1(F1),V1(F1),V2(F1),H1(F1)
230  DIM U1(4,F1),F5(4)
240  DIM P$(100),Q$(24),R$(25)
250  P$="LOG(PRESSURE)"
260  P$=P$&"LOG(SCALED IMPULSE)"
270  P$-P$&"LOG(PRESSURE EQUIVALENCY)"
280  P$=P$&"LOG(IMPULSE EQUIVALENCY)"
290  Q$="VS. LOG (SCALED DISTANCE)"
300  DIM C$(35),M$(35),T$(43),U$(55),X$(28),Y$(27),Z$(23),B$(1)
310  DIM V$(55),W$(27)
320  T$="PRESSURE AND IMPULSE VERSUS SCALED DISTANCE"
330  U$="PRESSURE AND IMPULSE EQUIVALENCY VERSUS SCALED DISTANCE"
340  X$="SCALED DISTANCE, ft/lb↑(1/3)"
350  Y$="PRESSURE AND SCALED IMPULSE"
360  Z$="PRESSURE TNT EQUIVALENCY"
370  DIM C(54),L(13)
380  DATA 1,2,4,6,10,20,40,60,100,200,400,600,1000
390  READ L
400  REM O = NUMBER OF POINTS FOR PLOTS AND TABULATIONS.
410  O=186
420  DIM J1(4,O),J5(O)
430  DIM PO(6),FO(3)
440  REM TNT EQUIVALENCY CALCULATION.
450  N1=1
460  PAGE
470  PRINT "MATERIAL?"
480  INPUT M$
490  PRINT "CONFIGURATION?"
500  INPUT C$
510  PRINT "APPROXIMATE % EQUIVALENCY?";
520  INPUT E5
530  S7-1
540  GOSUB 720
550  L9=0
560  IF L9 THEN 1810
570  IF N1=>P1 THEN 680
580  PRINT "MORE PASSES (Y/N)?";
590  INPUT B$
600  IF B$="N" THEN 680
```

```
610  S7=1
620  N1=N1+1
630  PAGE
640  PRINT USING 650:M$,C$,W1,W3
650  IMAGE "MATERIAL: ",35A/"CONFIGURATION: ",35A/"WEIGHTS: ",2(FD,FD,5X)
660  GOSUB 720
670  GO TO 560
680  L9-1
690  PAGE
700  GO TO 560
710  REM E MODULE.
720  01=0
730  02=0
740  03=0
750  04=0
760  05=0
770  06=0
780  07=0
790  08=0
800  PRINT "INPUT NUMBER OF CASES THIS WEIGHT, 0 TO END PASS"
810  INPUT C1
820  IF S7+C1<=31 THEN 850
830  PRINT "TOTAL CASES OVER 30"
840  GO TO 800
850  IF C1=0 THEN 1050
860  PRINT "INPUT W(lb), BOOSTER(lb),R(ft)"
870  INPUT W1,W3,R2
880  Z(N1)=R2/W1↑(1/3)
890  PRINT "INPUT P(psi),I(psi*msec)"
900  C1=C1+S7-1
910  FOR I=S7 TO C1
920  INPUT P(I),I1(I)
930  W5(I)=W1
940  W6(I)=W3
950  R9(I)=R2
960  N2=1
970  I1(1)=I1(I)/W1↑(1/3)
980  01=01+P(I)
990  02=02+P(I)↑2
1000  03=03+I1(I)
1010  04=04+I1(I)↑2
1020  NEXT I
1030  S7=C1+1
1040  GO TO 800
1050  GOSUB 1770
1060  FOR I=1 TO N2
1070  K2=-1
1080  PRINT "CALCULATING CASE";I
1090  IF P(I) <3.41 THEN 1170
1100  IF P(I) <11.53 THEN 1140
1110  A1=27.133
1120  B1=0.4513
1130  GO TO 1190
1140  A1=36.016
```

```
1150  B1=0.5672
1160  GO TO 1190
1170  A1=45.555
1180  B1=0.7557
1190  Z3=A1/P(I)↑B1
1200  E1(I)=((R9(I)/Z3) 3-1.25*W6(I))/W5(I) MAX 0
1210  W2=W5(I)
1220  E2(I)=0.01*E5
1230  Z2=R9(I)/W2↑(1/3)
1240  Z5=Z2/E2(I)↑(1/3)
1250  Z5=Z2>18 THEN 1330
1260  IF Z5>9 THEN 1300
1270  A2=47.247
1280  B2=0.8215
1290  GO TO 1350
1300  A2=55.874
1310  B2=0.8979
1320  GO TO 1350
1330  A2=67.37
1340  B2=0.9626
1350  B3=1/(1+B2)
1360  Z4=(A2*Z2/I1(I))↑B3
1370  E2(I)=(Z2/Z4)↑3
1380  W2=W5(I)+W6(I)*1.25/E2(I)
1390  K3=ABS(K2-E2(I))
1400  K2=E2(I)
1410  IF K3>1.0E-4 THEN 1230
1420  E1(I)=100*E1(I)
1430  E2(I)=100*E2(I)
1440  O5=O5+E1(I)
1450  O6=O6+E1(I)↑2
1460  O7=O7+E2(I)
1470  O8=O8+E2(I)↑2
1480  NEXT I
1490  Q1(1,N1)=O1/N2
1500  Q2(1,N1)=SQR((O2-O1↑2/N2)/(N2-1) MAX 0)
1510  Q1(2,N1)=O3/N2
1520  Q2(2,N1)=SQR((O4-O3↑2/N2)/(N2-1) MAX 0)
1530  Q1(3,N1)=O5/N2
1540  Q2(3,N1)=SQR((O6-O5↑2/N2)/(N2-1) MAX 0)
1550  Q1(4,N1)=O7/N2
1560  Q2(4,N1)=-SQR((O8-O7↑2/N2)/(N2-1) MAX 0)
1570  PAGE
1580  PRINT USING 1590:"TNT EQUIVALENCY OF",M$
1590  IMAGE 18X,19A,3X,35A/
1600  PRINT USING 1610:"CONFIGURATION:",C$
1610  IMAGE 14X,15A,3X,35A//
1620  PRINT USING 1630:"W","R","Z","P","I","E(P)","E(I)"
1630  IMAGE 4X,1A,9X,1A,10X,1A,2(9X,1A),6X,4A,3X,4A
1640  PRINT USING 1650:"lb","ft","SCALED","psi","SCALED","(%)","(%)"
1650  IMAGE 4X,2A,8X,2A,7X,6A,5X,3A,6X,6A,2(4X,3A)/
1660  FOR I=1 TO N2
1670  PRINT USING 1680:W5(I),R9(I),Z(N1),P(I),I1(I),E1(I),E2(I)
1680  IMAGE 1X,3D,3D,2X,4D,4D,3(2X,4D,3D),2(3X,4D)
```

```
1690  NEXT I
1700  PRINT USING 1710:"SUM",01,03,05,07
1710  IMAGE/18A,11X,2(6D.3D),2(7D)
1720  PRINT USING 1710:"MEAN",Q1(1,N1),Q1(2N,1),Q1(3,N1),Q1(4,N1)
1730  PRINT USING 1710:"STD.DEV.",Q2(1,N1),Q2(2,N1),Q2(3,N1),Q2(4,N1)
1740  GOSUB 1770
1750  RETURN
1760  REM PAUSE MODULE.
1770  HOME
1780  INPUT B$
1790  PAGE
1800  RETURN
1810  IF N1<=2 THEN 6080
1820  REM CALL CURVE FIT MODULE.
1830  C9=LOG(10)
1840  FOR I=1 TO N1
1850  X1(I)=LGT(Z(I))
1860  NEXT I
1870  FOR K=1 TO 4
1880  FOR I=1 TO N1
1890  Y2(I)=LGT(Q1(K,I))
1900  S2(I)=Q2(K,I)/(C9*Q1(K,I))
1910  NEXT I
1920  GOSUB 2010
1930  J0=(F9-1)*(F9+2)/2
1940  F5(K)=F9+1
1950  FOR I=1 TO F5(K)
1960  U1(K,I)=C(J0+1)
1970  NEXT I
1980  NEXT K
1990  GO TO 4120
2000  REM CURVE FIT MODULE.
2010  F=X1(N1)-X1(1)
2020  FOR I=1 TO N1
2030  X3(I)=X1(I)/F
2040  NEXT I
2050  FOR I=1 TO N1
2060  W(I)=1/S2(I)↑2
2070  NEXT I
2080  M1=N1-1 MIN 10
2090  Z1=0
2100  Z2=0
2110  Z3=0
2120  FOR I=1 TO N1
2130  Z1=Z1+W(I)*Y2(I)
2140  Z2=Z2+W(I)*Y2(I)↑2
2150  Z3=Z3+W(I)
2160  NEXT I
2170  R(1)=Z2-Z1↑2/Z3
2180  FOR J=2 TO M1
2190  J0=(J-2)*(J+1)/2
2200  K1=J-1
2210  GOSUB 2560
2220  PRINT USING 2230:M$,C$
```

```
2230 IMAGE 35A,X,35A/
2240 R$=SEG(P$,25*(K-1)+1,25)
2250 PRINT USING 2260:R$,Q$
2260 IMAGE 11X25A,1X24A/
2270 IF E>0 THEN 2490
2280 PRINT "FIT FOR DEGREE";K1
2290 PRINT "J          X             Y           FIT VALUE"
2300 Z1=0
2310 Z2=0
2320 FOR I=1 TO N1
2330 Z4=X3(I)
2340 GOSUB 3360
2350 PRINT X1(I),Y2(I),Y3
2360 Z1=Z1+W(I)*(Y3-Y2(I))
2370 Z2=Z2+W(I)*(Y3-Y2(I))↑2
2380 NEXT I
2390 FOR I=2 TO J
2400 C(J0+1)=C(J0+1)/F↑(I-1)
2410 NEXT I
2420 PRINT "JCOEFFICIENTS FOR DEGREE ";K1
2430 FOR I=J0+1 TO J0+J
2440 PRINT C(I);"I"
2450 NEXT I
2460 PRINT
2470 R(J)=Z2-Z1↑2/Z3
2480 GOTO 2510
2490 R(J)=(J-1)
2500 PRINT "JNO FIT WAS MADE FOR DEGREE";K1
2510 GOSUB 1770
2520 NEXT J
2530 GOSUB2910
2540 RETURN
2550 REM GAUSSIAN LEAST SQUARES MODULE.
2560 FOR G1=1 TO J
2570 FOR G2=1 TO J
2580 A(G1,G2)=0
2590 NEXT G2
2600 B(G1)=0
2610 C(J0+G1)=0
2620 NEXT G1
2630 FOR G2=1 TO N1
2640 Z4=X3(G2)
2650 GOSUB 3350
2660 FOR G3=1 TO J
2670 G(G3)=B(G3)+D(G3)*W(G2)*Y2(G2)
2680 FOR G5=G3 TO J
2690 A(G3,G5)=A(G3,G5)+D(G3)*W(G2)* D(G5)
2700 NEXT G5
2710 NEXT G3
2720 NEXT G2
2730 FOR G5=2 TO J
2740 G3=G5-1
2750 FOR G1=1 TO G3
2760 A(G5,G1)=(G1,G5)
```

```
2770  NEXT G1
2780  NEXT G5
2790  GOSUB 3460
2800  IF D1<>0 THEN 2830
2810  E=1
2820  GO TO 2890
2830  E=0
2840  FOR G1=1 TO J
2850  FOR G2=1 TO J
2860  C(J0+G1)=C(J0+G1)+A(G1,G2)*B(G2)
2870  NEXT G2
2880  NEXT G1
2890  RETURN
2900  REM F TEST MODULE.
2910  FOR I=2 TO M1
2920  R1(I)=R(I-1)-R(I)
2930  F=N1-I
2940  V1(I)=F*R1(I)/R(I)
2950  V2(I)=3.84+59.3*(I/F)↑2
2960  IF F>1 THEN 2980
2970  V2(I)=161.4
2980  NEXT I
2990  T1=0
3000  PRINT USING 2230:M$,C$
3010  PRINT USING 2260:R$,Q$
3020  PRINT "                          ANALYSIS OF VARIANCE TABLE"
3030  PRINT USING 3040:
3040  IMAGE /6X"DEGREE",11X"VARIANCE",10X"VARIANCE",10X"5 PERCENT"
3050  PRINT USING 3060:
3060  IMAGE 6X"OF TERM",11X"OF TERM",12X"RATIO",12X"F LEVEL"
3070  F9=0
3080  FOR I=2 TO M1
3090  J=M1+2-I
3100  K1=J-1
3110  PRINT USING "10D,8X,2(10E),9D.2D":K1(J),V1(J),V2(J)
3120  IF T1<>0 THEN 3160
3130  IF V1(J)<V2(J) THEN 3160
3140  T1=1
3150  F9=J-1
3160  NEXT I
3170  PRINT "J  RESIDUAL";R(M1)
3180  PRINT "       TOTAL';R(1)
3190  IF F9>0 THEN 3310
3200  PRINT "JNO DEGREE OF FIT WAS CHOSEN BY F TEST"
3210  FOR I=2 TO M1
3220  J=M1+2-1
3230  K1=J-1
3240  IF T1<>0 THEN 3280
3250  IF R1(J)<=0 THEN 3280
3260  T1-1
3270  F9=J-1
3280  NEXT I
3290  PRINT "DEGREE", F9; "WILL BE USED."
3300  GO TO 3330
```

```
3310 PRINT USING 3320:F9
3320 IMAGE/"OPTIMUM DEGREE OF FIT FROM F TEST =", 3D
3330 PRINT "J DO YOU WISH TO CHANGE DEGREE OF FIT (Y/N)?";
3331 INPUT B$
3332 IF B$<>"Y" THEN 3339
3333 PRINT "ENTER NEW DEGREE OF FIT";
3334 INPUT F9
3339 GOSUB 1770
3340 RETURN
3350 REM FUNCTION AND PARTIAL DERIVATIVE MODULE.
3360 D(1)=1
3370 Y3=C(J0+J)
3380 S3=J0+J
3390 FOR S1=2 TO J
3400 D(S1)=D(S1-1)*Z4
3410 S3=S3-1
3420 Y3=Y3*Z4+C(S3)
3430 NEXT S1
3440 RETURN
3450 REM MATRIX INVERSION MODULE.
3460 D1=1
3470 FOR L1=1 TO J
3480 H1(L1)=L1
3490 NEXT L1
3500 FOR L2=1 TO J
3510 IF L2=J THEN 3700
3520 H2=ABS(A(L2,L2))
3530 H3=L2+1
3540 H4=L2
3550 FOR L1=H3 TO J
3560 IF H2=>ABS(A(L1,L2)) THEN 3590
3570 H2=ABS(A(L1, L2))
3580 H4-L1
3590 NEXT L1
3600 IF H4=L2 THEN 3700
3610 FOR L3=1 TO J
3620 H5=A(H4,L3)
3630 A(H4,L3)=A(L2,L3)
3640 A(L2,L3)=H5
3650 NEXT L3
3660 L3=H1(H4)
3670 H1(H4)=H1(L2)
3680 H1(L2)=L3
3690 D1=-D1
3700 D1=D1*A(L2,L2)
3710 A(L2,L2)=1/A(L2,L2)
3720 FOR L3=1 TO J
3730 IF L3=L2 THEN 3750
3740 A(L2,L3)=A(L2,L3)*A(L2,L2)
3750 NEXT L3
3760 FOR L1=1 TO J
3770 IF L1=L2 THEN 3880
3780 H6=A(L1,L2)
3790 A(L1,L2)=-A(L1,L2)*A(L2,L2)
```

```
3800  FOR L3=1 TO J
3810  IF L3=L2 THEN 3870
3820  H7=H6*A(L2,L3)
3830  H8=A(L1,L3)-H7
3840  IF ABS(H8)=>1.0E-5*ABS(H7) THEN 3860
3850  H8=0
3860  A(L1,L3)=H8
3870  NEXT L3
3880  NEXT L1
3890  NEXT L2
3900  H9=J-1
3910  FOR L3=1 TO H9
3920  IF H1(L3)=L3 THEN 4020
3930  L2=H1(L3)
3940  H1(L3)=H1(L2)
3950  H1(L2)=L2
3960  FOR L1=1 TO J
3970  H5=A(L1,L3)
3980  A(L1,L3)=A(L1,L2)
3990  A(L1,L2)=H5
4000  NEXT L1
4010  GO TO 3920
4020  NEXT L3
4030  FOR L1=2 TO J
4040  I2=L1-1
4050  FOR L3=1 TO I2
4060  A(L1,L3)=(A(L1,L3)+A(L3,L1))/2
4070  A(L3,L1)=A(L1,L3)
4080  NEXT L3
4090  NEXT L1
4100  RETURN
4110  REM SET UP ARRAYS FOR PLOTTING.
4120  FOR I=1 TO 186
4030  J5(I)=LGT(3+0.2*(I-1)
4140  FOR J=1 TO 4
4150  GOSUB 4730
4160  J1(J,I)=Y3
4170  NEXT J
4180  NEXT I
4190  REM DRAW GRIDS.
4200  FOR K=1 TO 2
4210  IF K> THEN 4250
4220  V$=T$
4230  W$=Y$
4240  GO TO 4270
4250  V$=U$
4260  W$=Z$
4270  J=2*K
4280  Y4=J1(J-1,1) MIN J1(J,1)
4290  Y5=J1(J-1,1) MAX J1(J,1)
4300  FOR I=2 TO 186
4310  Y4=Y4 MIN J1(J-1,I)
4320  Y4=Y4 MIN J1(J,I)
4330  Y5=Y5 MAX J1(J-1,I)
```

```
4340  Y5=Y5 MAX J1(J,I)
4350  NEXT I
4360  FOR I=1 TO N1
4370  Y4=Y4 MIN LGT (Q1(J-1,I))
4380  Y4=Y4 MIN LGT (Q1(J,I))
4390  Y5=Y5 MAX LGT (Q1(J-1,I))
4400  Y5=Y5 MAX LGT (Q1(J,I))
4410  NEXT I
4420  GOSUB 4810
4230  REM DRAW CURVES.
4440  FOR M=2*K-1 TO 2*K
4450  MOVE J5(1),J1(M,1)
4460  FOR N=2 TO 186
4470  DRAW J5(N),J1(M,N)
4480  NEXT N
4490  REM PLOT POINTS.
4500  FOR N=1 TO N1
4510  MOVE LGT(Z(N)),LGT(Q1(M,N))
4520  SCALE 1,1
4530  IF M=2 OR M=4 THEN 4600
4540  RMOVE 0,1
4550  RDRAW 1,-2
4560  RDRAW -2,0
4570  RDRAW 1,2
4580  RMOVE 0,-1
4590  GO TO 4660
4600  RMOVE 1,1
4610  RDRAW 0,-2
4620  RDRAW -2,0
4630  RDRAW 0,2
4640  RDRAW 2,0
4650  RMOVE -1,-1
4660  WINDOW X4,X5,Y4,Y5
4670  NEXT N
4680  NEXT M
4690  GOSUB 1770
4700  NEXT K
4710  GO TO 5660
4720  REM POLYNOMIAL EVALUATION MODULE.
4730  L9=F5(J)
4740  Y3-U1(J,L9)
4750  FOR K=2 TO F5(J)
4760  L9=L9-1
4770  Y3=Y3*J5(I)+U1(J,L9)
4780  NEXT K
4790  RETURN
4800  REM GRID DRAWING SECTION.
4810  VIEWPORT 23,107,16,100
4820  X4=LGT(2)
4830  X5=LGT(40)
4840  J=10↑Y4
4850  GOSUB 5540
4860  Y4=LGT(X)
4870  J=10↑Y5
```

```
4880 GOSUB 5540
4890 Y5-LGT(Y)
4900 WINDOW X4,X5,Y4,Y5
4910 H=0
4920 Z2=X5 MAX Y5
4930 FOR I=10↑H TO 10 (H+1) STEP 10↑H
4940 IF 1>10 Z2 THEN 4960
4950 AXIS 0,0,LGT(I),LGT(I)
4960 NEXT I
4970 H=H+1
4980 IF H<Z2 THEN 4930
4990 FOR I=2 TO 7
5000 MOVE LGT (L(I)),Y4
5010 PRINT "HJ"; L(I);
5020 NEXT I
5030 I2=0
5040 I3-I3
5050 FOR I=1 TO 13
5060 IF L(I)<10↑Y4 THEN 5090
5070 IF I2<>0 THEN 5090
5080 I2=I
5090 IF L(I)<=10↑Y5 THEN 5120
5100 I3=I-1
5110 IF 13<13 THEN 5120
5120 NEXT I
5130 FOR I=I2 TO I3
5140 MOVE X4, LGT(L(I))
5150 PRINT "HHH"; L(I);
5160 NEXT I
5170 MOVE (X4+X5)/2,Y4
5180 PRINT "JJ";
5190 FOR I=1 TO LEN (X$)/2
5200 PRINT "H";
5210 NEXT I
5220 PRINT X$;
5230 MOVE X4,Y4+1.41*(Y5-Y4)/85
5240 FOR I=1 TO 4
5250 PRINT
5260 NEXT I
5270 PRINT USING 2230:M$,C$
5280 MOVE (X4+X5)/2,Y4
5290 PRINT "JJJJJ";
5300 FOR I=1 TO LEN (V$)/2
5310 PRINT "H";
5320 NEXT I
5330 PRINT V$
5340 MOVE X4,(Y4+Y5)/2
5350 PRINT "HHHHH";
5360 FOR I=1 TO LEN (W$)/2
5370 PRINT "K";
5380 NEXT I
5390 FOR I-1 TO LEN(W$)
5400 B4=SEG(W$,I,1)
5410 PRINT B$;"HJ;
```

```
5420  NEXT I
5430  T=(Y5-Y4)*0.01
5440  MOVE LGT(5.4),Y4+T
5450  DRAW LGT(5.4),Y4
5460  MOVE LGT(18),Y4+T
5470  DRAW LGT(18,)Y4
5480  MOVE LGT(5.4),Y5
5490  DRAW LGT(5.4),Y5-T
5500  MOVE LGT(18),Y5
5510  DRAW LGT(18),Y5-T
5520  RETURN
5530  REM FIND AXIS LIMITS BASED ON DATA VALUES.
5540  DEF FNA(J)=INT(ABS(J)*Z1)
5550  Z1=1
5560  IF FNA(J)<10 THEN 5620
5570  Z1=Z1*10
5580  GO TO 5560
5590  IF FNA(J)<10 THEN 5620       IF FNA(J)<10 THEN 5620
5600  Z1=Z1/10
5610  GO TO 5590
5620  X=INT(J*Z1)/Z1 MAX 1
5630  Y=INT(J*Z+1)/Z1 MAX 1
5640  RETURN
5650  REM PRINT COEFFICIENTS USED.
5660  FOR K=1 TO 4
5670  PRINT USING 2230:M$,C$
5680  R$=SEG(P$,25*(K-1)+1,25)
5690  PRINT USING 2260:R$,Q$
5700  PRINT USING "30X12A":"COEFFICIENTS"
5710  FOR J=1 TO F5(K)
5720  PRINT U1(K,J);"I";
5730  NEXT J
5740  PRINT USING "//":
5750  NEXT K
5760  GOSUB 1770
5770  REM PRINT TABULATIONS.
5780  F0(1)=0.3967
5790  F0(2)=6.895
5800  F0(3)=8.974
5810  FOR I=1 TO 186
5820  IF I-INT (I/25)*25<>1 THEN 5960
5830  PRINT USING 2230:M$,C$
5840  PRINT USING 5850:
5850  IMAGE 10X"PRESSURE OR IMPULSE AS A FUNCTION OF SCALED DISTANCE"/
5860  PRINT USING 5870:
5870  IMAGE 3X"SCALED",5X"SCALED",27X"SCALED",9X"SCALED"
5880  PRINT USING 5890
5890  IMAGE 2X"DISTANCE",3X"DISTANCE",2(2X"PRESSURE"),2(5X"IMPULSE",3X)
5900  PRINT USING 5910:
5910  IMAGE 2(7X"1/3"),21X2(12X"1/3)
5920  PRINT USING 5930:
5930  IMAGE "(ft/lb  )(m/kg  )",3X"(psig)",5X"(kPa)",3XS
5940  PRINT USING 5950:
5950  IMAGE "(psi-ms/lb  ) (kPa-ms/kg  )"/
```

```
5960  (PO(1)=10↑J5(I)
5970  PO(2)=FO(1)*PO(1)
5980  FOR J=2 TO 3
5990  PO(2*J-1)=10↑J1(J-1,I)
6000  PO(2*J)=FO(J)*PO(2*J-1)
6010  NEXT J
6020  PRINT USING "2(5D.3D,2X),2(5D.2D,2X),2(7D.2D,5X)":PO
6030  IF I-INT (I/25)*25<>0 THEN 6050
6040  GOSUB 1770
6050  NEXT I
6060  GOSUB 1770
5070  REM FINISHED.
6080  STOP
```